The
ENGINEERS' DIGEST
REVIEW OF WORLD ENGINEERING PROGRESS

VOL. XIV No. 11. NOVEMBER 1953

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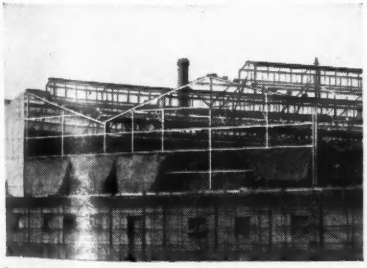

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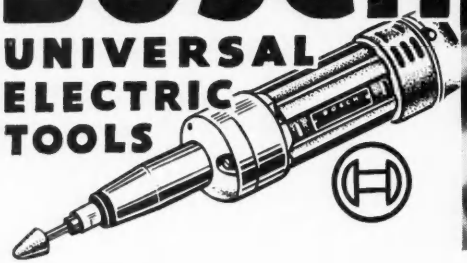

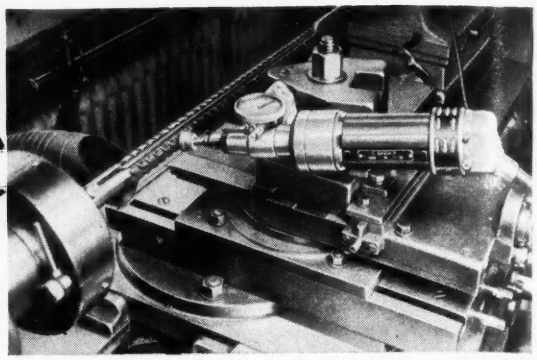

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The ENGINEERS' DIGEST

REVIEW OF WORLD ENGINEERING PROGRESS

VOL. XIV. No. 11 NOVEMBER, 1953

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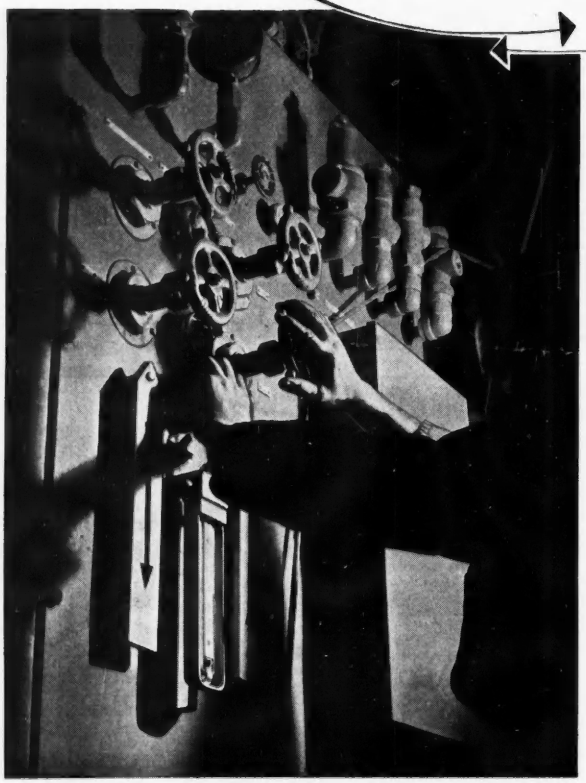

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THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *NEW CASTING TECHNIQUE*

A new die casting technique has been developed, which may well serve to eliminate the need for many expensive dies, where the desired shape of the new part is similar to that of a standard casting already in production; in fact, this new technique may enable the manufacture of limited numbers of castings to be carried out, where the cost of a complete new die would be prohibitive. The development of the new method was due to the observation in a specific case that, by constructing a die, the cavity of which would form the new shape on the end of the main casting, revised shapes and dimensions could be fuse-cast to the standard part at approximately one quarter of the cost of a new die. The equipment needed for this process is an induction heater and a die, which is constructed to form the revised dimensions, with apertures to hold the cut-off ends of the standard casting. About four inches of these cut-off ends are first brought to a temperature of about 400 to 420° F in the heater before inserting them in the die. This allows the end of the casting to fuse solidly with the molten zinc alloy in the casting die. Gating in the die is such that the zinc alloy injected into the new cavity flows across and melts part of the hot, cut-off end of the inserted casting, fusing with it before the newly cast portion freezes in the die. When the altered die is in use, the induction heater, which is kept adjacent to the die casting machine, is loaded by the operator, while the casting machine runs through its normal automatic cycle.

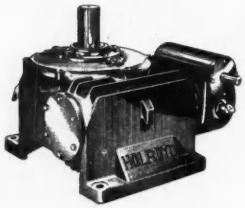
● *OXIDE FILM ON NICKEL-CHROMIUM ALLOYS*

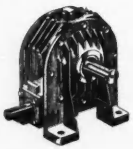
Because of their high resistance to oxidation, the 80 per cent Ni—20 per cent Cr alloys are one of the most useful alloy systems. Over the past 30 years, the performance of alloys of this nominal composition in cyclic oxidation tests has been improved by over 600 per cent, by reducing the manganese content, increasing the silicon content, and adding minor amounts of calcium, aluminium, zirconium, cerium, etc. Because of the complexity of the problem, comparatively little scientific work has been directed towards understanding the oxidation resistance properties of these alloys. The essential problem is to determine what factors in the composition and crystal structure of the oxide film and alloy can be related to the improved protective properties. A report has now been issued, relating crystal structure studies made on eight alloys of the group under reference. In these the silicon and manganese compositions were varied systematically. The alloys were oxidised over a temperature range of 400 to 950° C, and over a time range of one hour for an oxygen pressure of 1 mm of mercury. Although the 80 per cent Ni—20 per cent Cr alloys of low manganese composition showed a 300 per cent improvement as a result of increasing silicon alone, the crystal structures and compositions of the oxides showed no appreciable differences. Nickel oxide was formed at temperatures of 400 and 500° C. A larger variation in the manganese content greatly altered the crystal structure of the oxide. However, for a one per cent silicon alloy, the useful life was independent of the manganese content. It is concluded that there is no unique oxide composition for satisfactory protection to cyclic tests. Instead, it is suggested that the useful life can be correlated, not with normal oxidation processes, but rather with changes in the physical properties of the alloy-oxide interface.

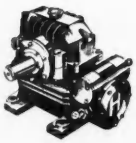
● *RAPID STEEL ANALYSIS*

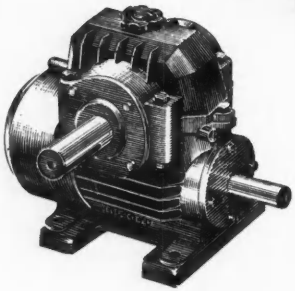
By installing specially designed high-speed spectrographic equipment and by effectively organising collaboration between laboratory and plant, a steel mill has found it possible to reduce the time required for the analysis of a heat from ½ hour to a few minutes. Depending upon the elements present in the steel, a complete analysis formerly could not always be obtained during the melting period. With the new spectographic plant, a test sample can be sent from the melting shop through a pneumatic tube to the laboratory. The sample is polished, excited by arc or spark in the spectroscopic unit, and the complete analysis of all metallic elements present read instantly from a chart and reported back to the melters. It is claimed that this instrument is the first production control unit installed for the complete chemical analysis of tool steel, high-speed steel, stainless steel, low alloy steels, and high-temperature alloy steels. A unique property claimed for the instrument is that it will analyse material which is either iron base, cobalt base, or nickel base. Its manufacturers point out that the instrument utilises every available electrical channel which can be built into an instrument designed for routine control. The unit consists of three parts, namely,

the things they make at Holroyd's









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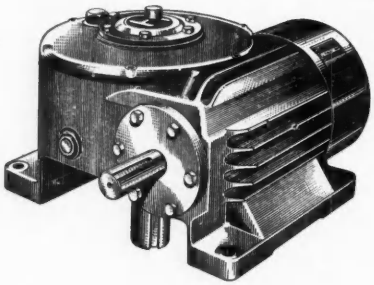
Holroyd's have written a book about their Worm Gear Reduction Units. It gives full details on their Underdriven, Over driven and Vertical Type Units—selection and service, horsepower and torque, dimensions, efficiencies, lubrication and maintenance — all the facts a worm gear user needs. They'll be glad to send you a copy, together with information on the other three kinds of Worm Unit shown above, (the 'F' and double reduction types). Their address is John Holroyd & Co., Ltd., Milnrow, Lancs.



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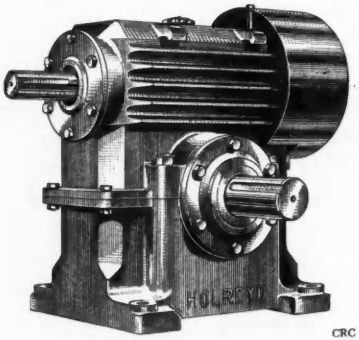

CRC 163

a high-precision source unit, a spectrometer, and a recording console. The high-precision source unit delivers a discharge current rigidly and reproducibly controlled as to voltage, amperage, frequency, and wave form. Discharge time is twenty seconds and reading is about three seconds per element. It is stated that the use of the instrument results in better control of residual elements which formerly could be determined only after the steel had solidified.

● *IMPROVED REFRACTOMETER*

An improved refractometer for rapid and accurate measurement of the index of refraction has recently been developed. With this new instrument the index of refraction of specimens of glass or some other optical materials can be determined with high accuracy in a matter of minutes. It is claimed that costly and time-consuming grinding and polishing operations, normally required when index-of-refraction determinations are made with other refractometers or spectrometers, are eliminated. The instrument consists of a light source, a horizontal filament, a collimator, a diaphragm, a pair of 45-90 deg cemented prisms forming a 90-deg hollow at the upper half and a parallel plate at the lower half, a filar micrometer, and a telescope. All the components are centrally aligned along a common horizontal axis. To determine the index of refraction of a piece of glass with this refractometer, the sample is merely cut with a 90-deg edge, no grinding or polishing being needed, and fitted into the 90-deg hollow of the cemented prism assembly. An immersion liquid, having the approximate refractive index of the sample, is used as a contact liquid between the sample and the prism. The observer sees two images of the illuminated filament ; the lower half of the optical system produces a direct image, and the upper half of the system gives an image which has passed through the glass sample and has been refracted. Either image can be blocked out by the use of the diaphragm. The separation of the upper image from the lower image is a measure of the index of refraction of the sample and its magnitude may be determined with the filar micrometer. Calibration of the micrometer in terms of index of refraction is a simple matter.

● *NEW PROCESS FOR STEEL INGOT PRODUCTION*

A new process for the production of steel ingots of especially high-grade steel has been developed. In this process steel, made in an open hearth furnace or in an electric furnace, is post-treated in an inductively heated mould, which is constructed as a coreless induction furnace and charged with alternating current of network frequency. At the same time, cooling of the mould is effected by a water and compressed air cooling system, which consists of a cooling coil incorporated in the mould and enveloping the ingot. The heating current and the flow of cooling water are so adjusted that no temperature increase in the ingot takes place. Owing to the low frequency of the heating current, the inductive effect of the current extends to a comparatively great depth into the steel. This treatment is kept up until the impurities, such as slag, as well as the gases and oxides, have had sufficient time to separate off. The weak movement of the bath prevents any temperature difference from being set up in the ingot and ensures substantial homogenisation. When the supply of heating current is reduced, the first crystals are formed on the walls of the mould, as a result of the heat dissipation effected by the water cooling. Owing to the penetration of the mould contents by the induced currents, which are at maximum strength at the interface between the mould and the ingot, and owing to the persistently weak movement of the bath, there is less tendency for harmful columnar grains to be formed. It is also claimed that dissociation phenomena and reactions, resulting in an evolution of gas and the liquation zone characteristics of larger ingots, are largely or completely absent.

● *NEW TUMBLING PROCESS*

Horizontally rotating barrels or boxes for cleaning or scrubbing parts, cast or forged, have been in use for many years. The parts are tightly packed in barrels, sometimes together with slag, scrap, or specially made slugs. The rate of rotation is high, e.g., 100 rpm or more, and the parts thus knock or grind against each other. The object of this process is to remove sand, soot, or mill scale and, in other words, to clean the parts, to fettle them, and at the same time to break away or knock off sharp edges, flash, or burrs. Hence, the process is called tumbling. It is often carried out in the dry state and is completely uncontrollable. It is simply a question of the parts knocking and scraping against each other, and the whole operation is allowed to run as best as it may. The author of a recent paper on this subject points out that a more advanced process is mainly based upon the principle that, during processing, the parts never touch each other, but are always well embedded in a medium of a specially prepared type. This medium contains the grinding or burnishing materials, exactly chosen with regard to shape, size, and physical surface properties. For every job there is a definite amount of water, to which are added chemical agents, each serving a different purpose. These agents are chosen according to the material of the parts to be treated and the surface finish required. The speed of rotation of the barrel is very much less than that of the ordinary tumbling process and so chosen that, because of its friction against the barrel walls, the whole charge is raised to a definite angle of repose. On further rotation, a certain depth of the upper or sliding

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layer is continually rolling and tumbling back to the bottom of the barrel. The parts are always embedded in the medium and thus are subjected to the friction or grinding action and to the pressure created by the load. The process is not dependent on skilled operators and important financial savings are claimed for it.

● *TELEVISION AS A RESEARCH INSTRUMENT*

A considerable amount of information has been obtained in recent years by using television as an observation instrument, and it can be expected that there will be a steady increase in the use of television as a research tool, once its advantages become more widely known. Television has been particularly valuable in recent research on rocket engines, where many untried propellants are poisonous and corrosive. In one particular case, the safety of personnel conducting hazardous experiments with untried propellants was ensured by equipping a remotely-located test cell with television, so as to permit remote observation of a rocket in operation. For this purpose, a special cubicle was constructed for the television camera and mounted on skids to facilitate mobility. In addition to the important role played by television as a means for observing rocket operation, it has also proved helpful in supervising the operation of the individual rocket components. Thus, for instance, in one case the television monitor was able to warn that a propellant valve had failed to open; this enabled the operating engineer to shut down the rocket immediately and to prevent the wastage of expensive fuel. Another promising application of television equipment is found in wind tunnel tests. Where research in a supersonic tunnel is carried out with the aid of Schlieren apparatus, television equipment can be used to enable the operator in the control room to observe a televised Schlieren image and to adjust the air flow in order to produce the required Schlieren pattern. As reported in these pages last May, the observation of water columns on large boilers by means of television has already become a feature of modern boiler room practice, and may easily prove the forerunner of a comprehensive system of television supervision instrumentation, designed to cover a wide range of operations.

● *PROTECTION OF INOPERATIVE TURBINES*

A new method of maintaining inoperative turbines free from corrosion consists in applying a film of corrosion inhibiting oil to the internal parts of the machine. In order to apply the oil, it was hitherto necessary to open the casing, thereby entailing a considerable amount of work. An attempt was made to circumvent this need for opening the machine by injecting oil and then ensuring its even distribution by blowing steam through the turbine. This method proved fairly successful in the case of small units of up to 1000 kW capacity, but failed with larger units. By systematic research and development, a treatment has finally been evolved which makes it possible to apply a continuous and uniform coating of corrosion-inhibiting oil to the internal parts of steam turbines of any size without having to open the casing. Moreover, while giving complete protection for a considerable length of time, the oil film can be easily removed by washing the unit with wet steam when warming up and turning over. The actual procedure consists in injecting the corrosion-inhibiting oil in an atomised state into a mixing chamber, steam being used as the atomising method. At the same time, live steam is introduced into the mixing chamber, and the steam and steam-oil mixture is then passed into the turbine to be treated. Treatment is carried out while the turbine is turning over slowly and the turbine internals are at a temperature of approximately 430° F, apparently the optimum temperature for treatment. The amount of corrosion-inhibiting oil required is stated to be small, only some $\frac{3}{4}$ gal of oil being needed in the case of a 4000 kW turbine.

● *PLASTIC COATINGS*

Vinyl plastic coatings or vinyl plastisols, as they are frequently called, exhibit outstanding resistance to corrosion, remarkable toughness, and resiliency. Because of these properties, they are highly suitable as coatings on metal parts which are exposed to corrosion and which formerly had to be made of highly alloyed ferrous and non-ferrous alloys. Vinyl dispersion plastisols are suspensions of resin in non-aqueous liquids which do not dissolve the resin at ordinary temperatures. They often include other ingredients, such as stabilisers, pigments, fillers, etc. Plastisols require heat to fuse the material into a continuous film. These coatings differ completely from types of solution containing volatile solvents, where the film of resin forms, at least partially, by solvent evaporation. Plastisols contain no such volatile constituents. When the plastisol, i.e., a mixture of resins and a plasticiser, is heated to proper temperature, the solid particles of resin dissolve in the liquid plasticiser. On cooling, a rubber-like material is formed. This material, which has remarkable corrosion and heat-resistant properties, can be extruded, dip-moulded, or dip-coated. It can be coated on paper or fabric, cast into sheet, or spray-coated. After the liquid plastisol has taken the desired shape or form, heat is applied for curing. Temperature is an important factor and controls the nature of the product, as well as the thickness of the coating. Curing temperatures generally range from 350 to 375° F, although some special lower temperature modifications have also been developed.

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THE GREATEST NAME IN "NICHROME" ELECTRICAL RESISTANCE

● *TOUGHENING OF PLASTICS BY ELECTRON BOMBARDMENT*

It has recently been found that startling chemical changes can be brought about by electronic action, i.e., by exposing materials to bombardment by electrons. Thus, a brief bombardment by electrons can be employed to toughen polyethylene plastics, so that containers made of this material can withstand sterilisation by steam. Certain liquid substances can be turned into solids at temperatures as low as —100° F. In the case of wood and cellulose, it has been found possible to lower their molecular weight, i.e., to depolymerise these materials. Bread, vegetables, and other foods after exposure to electron treatment have been found to remain fresh over relatively long periods of time. In the case of polyethylene plastics, the toughening caused by electron bombardment would appear to be the result of chemical change and it is thought that electron bombardment, even for only a few seconds, causes the chain-like molecules to cross-link. This structural "weaving" not only increases the resistance of the plastic to temperature but also improves its resistance to the corrosive action of some solvents. Steps have already been taken to utilise this discovery for commercial processes. One of the applications reported is the processing of polyethylene containers used for pharmaceutical products, including blood plasma. In the past, polyethylene could not be used for purposes where sterilisation of the container was required, as the material collapsed when subjected to such temperatures. By controlling the pattern of an electron beam bombarding liquid plastics, it was found that the portions exposed to the beam could be solidified and this phenomenon is now being used to form the basis of an entirely new technique of casting and forming plastic articles.

● *FLAME CONTROL BY ELECTROSTATIC FIELD*

A recent invention envisages control of the generation, flow, and application of heat by providing an electrostatic field between the flame and the part to be heated. To be effective in commercial applications, a potential gradient in excess of about 1500 volts per inch between flame and heated object is stipulated. The inventors state that, for example, where a flame from a combustible gas or vapour is polarised by connecting the flame or the burner with the positive terminal of a high potential direct current source and the object to be heated with the negative terminal, several remarkable phenomena take place. The temperature of the flame is increased, while the flame, and with it the heat generated, are caused to flow towards the object. Combustion conditions are improved, all soot and dirt being eliminated, and the flame burns with a clear, bright, bluish flame. The possibility of concentrating the flame upon an object by means of an electrostatic field is not limited to flames and heated media originating from combustible solid, liquid, or gaseous substances, but can, it is stated, also be applied to the electric arc. In this case, one of the electrodes producing the arc can be connected to the positive terminal of high potential current and the negative terminal can be connected to the object towards which the arc is to be directed. The arc will then bend out of its normal path towards the polarised object, thus assisting in concentrating the heat on the object. Also, the arc apparently increases in intensity. An early investigation of the practical possibilities of this invention, which is based upon a well-known electrostatic phenomenon, would certainly appear indicated.

● *SPARK THROWING OF METALS*

"Non-sparking" tools or equipment of hardened copper have acquired a good reputation in the minds of those responsible for safety in places where explosion hazards exist. Possibly because hard steel is so often the alternative construction material and because hardened copper is relatively soft in comparison with steel, the impression may have been created that sparks are thrown off only from hard and comparatively brittle metal. It may therefore be surprising to know that sparks can be thrown from aluminium, magnesium, or brass when struck against concrete or steel. This is a curious phenomenon, especially where such a soft metal as magnesium is concerned. In the case of this metal, it has been suggested that the spark may be due to the presence of a chromate film, which is known to produce a sparkable coating on magnesium. This may have been so in certain cases but, in fact, a coating is apparently not necessary for sparking to occur and friction alone can produce sparks from magnesium. For example, if a very fine cut is taken on magnesium with a dull tool, the chip may ignite, or if a good tool idles against the work at the end of a cut, the fine particles torn off may burn. Sparks occur now and then when castings are ground with abrasive wheels, and an abrasive cut-off disc will throw off a shower of dangerous sparks unless the work and the tool are flooded with a coolant. Thus, it is not necessary for a metal to be hard to throw off a spark. If the manner of impact is such that a small particle of soft metal is torn off and if the energy of impact is great enough to heat this particle to its ignition temperature in air, a spark will occur.

For further information on developments reviewed in THE BLUE PAGES, readers are invited to write to the Editor.

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THE ENGINEERS' DIGEST

REVIEW OF WORLD ENGINEERING PROGRESS

VOL. XIV. No. 11. NOVEMBER, 1953

LITTLE MOTHER OF INVENTION

As our readers are aware, we publish a considerable number of articles from Russian sources. Let us hasten to add that, of the mass of material received, comparatively little is included in our pages, principally because of the exuberance of Russian claims to originality.

If we are to believe only a few of the most solemn Soviet pronouncements, Galilevich invented the telescope and Whittlevich the jet-engine; Columbovich discovered America, the brothers Wrightovich conquered the air, Newtonovich formulated the Law of Gravity, Faradavich paved the way to electrical power generation, and Baconovich wrote Shakespeare. If these are not actually the real names of the alleged claimants, our excuse is that, in view of their ever-growing numbers, it is getting increasingly difficult for us to tell *vich* from *vich*.

Is it any wonder, then, dealing as we are with a nation which appears to have invented everything and everybody, with the possible exceptions of an English summer and Churchill, that we are inclined to treat their technical information with the gravest suspicion. Every source of Russian information is carefully sifted, every item carefully analysed. In many cases, we have noticed claims to originality which, on investigation, have proved to be entirely unfounded. In short, when dealing with Russian technical literature, our policy is not so much to take things as read, but rather to take them as Red.

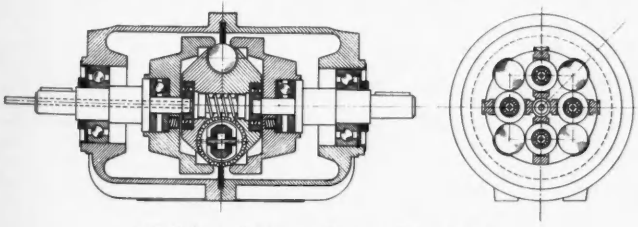
Once in a while, however, something may escape even our most careful scrutiny. Recently, we received a courteous letter, with documentary evidence, from Messrs. Contraves A.-G., of Zurich, pointing out that, in an article on "Recent Advances in Soviet Machine Tools," in our issue of June, 1953, an infinitely variable speed gear, described as an "original Russian design," has, in fact, been constructed and marketed by this firm for about 15 years. So that our readers may judge for themselves, we reproduce drawings of both gears, from which it will be apparent that, with the exception of slight differences in detail, the gears are of identical design. Accordingly, we offer our apologies and thanks to our Swiss friends for calling our attention to this lapse on our part. In our own defence, however, we should add that this is only the second occasion on which our attention has been called to an error of this sort.

What can Russia possibly hope to benefit by such claims? In the case of the above-mentioned gear, it is possible, of course, that a member of some enterprising Muscovite Commission purchased one in Switzerland, copied it, and then foisted it off on his credulous fellow-countrymen as an original creation. That, at any rate, seems the most likely, and possibly the most charitable, explanation. In the case of their more extravagant and absurd claims, however, we are at a loss to find a satisfactory solution. In Russia, self-styled Little Mother of her people, there are both brains and ability but, like the little boy who shouted "Wolf, wolf!" in the fable (by the famous Russian peasant, Aesopovich), surely this constant insistence on the palpably false is likely to engender a natural disbelief in even genuine ability, which, at the moment, would appear to consist merely of a prolific genius for inventing inventors.

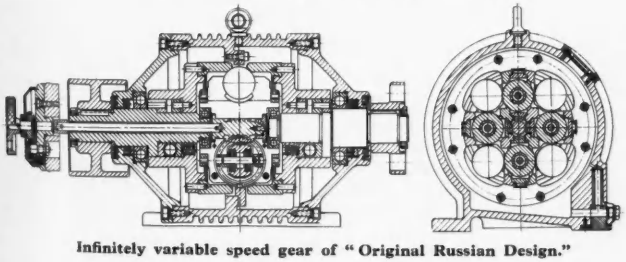
As a matter of fact, many of the world's outstanding inventions are not the products of one man's ingenuity, but are, in essence, the results of a fusion of the efforts of many men, often of different nationalities, doubtless including Russian. If, then, the U.S.S.R. confined its claims to international inventions of this kind, there might be some point in these attempts to scoop the pool, as it were. In the case of other inventions, some of them of relative unimportance, the origin of which has already been incontrovertibly pinpointed for years, such attempts would seem as illogical as they are unfounded.

It may, of course, be argued that these extravagant claims to inventive genius are not intended to be taken seriously outside the U.S.S.R., but are only for home consumption, so to speak. If that is so, it is still a poor policy, for even the Russians must be aware of the futility of trying to "fool all of the people all of the time," as the celebrated Soviet statesman, Abrahamsky Lincolnovich, so aptly put it.

For our part, we intend to continue publishing articles from Russian sources, in the sincere belief that they are interesting, even at times instructive, though we propose to separate the grain from the chaff with even greater circumspection than before, if such is possible. In the meantime, however, as a *quid pro quo* (to use the ancient Russian Latinsky dialect), we suggest an intensive counter-propaganda to the effect that the Sadler's Wells Ballet invented Pavlova, and that one of Russia's most famous Marshals is really a renegade Irishman by the name of Tim O'Shenko.



Infinitely variable speed gear of Swiss design



Infinitely variable speed gear of "Original Russian Design."

Symposium on Engineering Metrology—National Physical Laboratory

THE Metrology Division of the National Physical Laboratory recently organised a four-day symposium on Engineering Metrology, which was extremely well attended by experts from many countries and in which several prominent metrologists presented papers in the following groups :—Workshop inspection, pneumatic gauging, machine tool accuracy, education, gear measurement, small-scale measurement, large-scale measurement, and surface finish.

Whilst engineering measurements until recently were almost exclusively performed with fixed gauges, the introduction and universal use of the screw micrometer in workshops foreshadowed the advent of high-precision measuring instruments, and to-day optical, electrical, and pneumatic instruments are claimed to be able to control the operation of machines to such an extent that truly accurate workpieces, with no rejects, are obtainable.

As pointed out by J. E. Sears, the predecessor of the present superintendent, H. Rolt, and one of the first workers in metrology at the N.P.L., any progress in measuring technique will ultimately lead to a progress in production techniques. This indicates the important role of the N.P.L. in using and developing measuring methods of higher accuracy than those required in the actual workshop, even in precision engineering.

The question of surface finish aroused considerable attention. A comprehensive analysis of what surface finish involves was presented by E. R. Reason. Much thought has been devoted on how to make truly accurate measurements of surface finish, and in this respect the work in America by F. A. Underwood in producing hard nickel- and rhodium-plated reference standards, produced as replicas from diamond-ruled, gold-plated surfaces, has been accepted as a big advance. These control both the depth and the form of groove, whilst the earlier developed N.P.L. glass standards merely control the depth. An important question was whether actual surface finish standards are useful or not. The idea that the draughtsman should specify the surface quality on his drawing was deprecated ; it was preferable, rather, that the correct surface finish number should be ascertained after the prototype machine had been worn in and tested.

The pneumatic gauging principle aroused very great interest. There was some discussion as to who was the inventor of the method, but there seemed to be general agreement that this method was first applied practically in France, and that it was probably the firm of Solex who first used it for checking the size of carburettor nozzles, before it was applied to the motor industry and subsequently to many other industries which were obliged to make multiple measurements on the same component. The first-mentioned application has already indicated some of the advantages and disadvantages of this method, which in the course of years have been eliminated, or at least mitigated, by suitable apparatus. For instance, if the surface roughness of a component is not controllable, then the direct measurement, i.e., the flow of fluid against the surface, may lead to errors and an indirect principle of measurement has to be applied. Alternatively, the influence of the air pressure only, due to surface roughnesses, has led P. Nicolau to the invention of a surface finish tester, and the N.P.L. has made interesting measurements with this method, the originator of which was present at the Symposium. With various surface finishes of ground surfaces, it was found that the increase in pressure was almost proportional to the roughness. Alternatively, diamond-turned surfaces had another factor of proportionality. J. C. Evans discussed the fundamentals of this method, according to which, operations should be effected in a field of linearity between the ratio of pressures and the ratio of the area of openings, a condition which was not fulfilled by the pneumatic method applied by the Phys. Techn. Bundesanstalt for measuring the load dependency of proving rings. In this method, gauge-blocks of different sizes are inserted between two air nozzles and only a critical gap width is adjusted.

Besides the simple water gauge, as originally introduced by Solex, other pressure gauges are now used and their development was reviewed by F. R. Boosey. He also pointed out the great facility of operating a recorder, which was demonstrated for the control of extruded material and for a hardness tester indicating a depth of penetration up to 5 microns and necessitating a magnification of $\times 20{,}000$. The N.P.L. has carried out interesting investigations with improved pneumatic gauges, in particular with transducers for amplifying the recording force for determinating cross-sectional variations in textile materials and insulated wire.

A new development is a two-stage comparator with one nozzle blowing against a master and the other against a specimen, while a third nozzle is arranged opposite a diaphragm capsule for increasing the force with which the indicating unit is operated. The high accuracy obtainable in optical gauging was well demonstrated by the new N.P.L. comparator for measuring ring gauges, making use of an autocollimator. The accurate angular measurement obtained with this instrument is converted by means of a lever and feelers into differential measurements. A very high accuracy can be obtained with this instrument, which will be made available in an industrial model.

The interferometric method has long been used for checking gauge-blocks, but has extended its use to the investigation of surfaces, as was ably shown by A. Mirau of the Laboratoire Centrale d'Armement. To-day, by the use of silvered surfaces and dichroic mirrors, even the multiple-beam interferometric method can be applied to the determination of surface quality, though, naturally, the interpretation of the interferograms for workshop use is not as easy as with surface finish instruments operating with mechanical feelers.

Another optical principle is that of the contact of a prism with the surface to be tested. Such an instrument was first developed by two Frenchmen in 1926, and now commercial apparatus of this type is available in France and Germany.

Interesting new principles were demonstrated by J. Turrettini for projection methods, which, although specially developed for checking the contours of turbine blades, actually solved a number of most important measuring and control problems. The ultimate effect is a thin, white line indicating the cross-section of the component on the screen, it being possible to see even two different sections at the same time. R. E. Reason referred to earlier work in this respect in this country, but the Société Genevoise may be the first firm to market this equipment.

A. Mirau referred to a method of optical integration for determining the degree of polish of a surface by means of a beam of light reflected, for instance, from a gun-barrel. This principle was first developed by Canac in 1937, and is now an accepted method of die inspection, based mainly on the principles of Elder. Apparatus of this type is now manufactured in America, Germany, and England for controlling the angle of die bores.

J. Turrettini described another simple reflecting method for cylindrical bores, by means of the insertion of a polished cone. This method, whilst probably new

(*Concluded on page* 444)

Fully Automatic Production of Resistance-Welded Wire Mesh

By H. WEDL. (From *Draht*, June, 1953, pp. 205-211, 16 illustrations.)

The design and manufacture of plant for the fully automatic production of resistance-welded wire mesh pre-suppose the solution of a series of metallurgical, mechanical, and electrical problems. These problems and their solutions are dealt with below, by reference to a mesh welding plant which is in fully automatic operation and which includes automatic feeds to and from the machine.

METALLURGICAL PROBLEMS

For the manufacture of welded wire mesh by fully automatic machines, unalloyed steel wires are used which have been cold formed (drawn) to the required size, the mechanical properties of the wires being determined by the ultimate application. Electrical resistance welding of soft steel wires with a carbon content of approximately 0·1 per cent does not present a metallurgical problem. If the correct technique is used, the presence of the weld area has no effect on the strength of the wires. The circumstances are different, however, in the case of steels which have a somewhat higher carbon content and which, owing to previous cold working, also have an increased tensile strength.

Investigations of different weld areas of such wires joined by electrical resistance welding showed without exception a perfect, i.e., a fully bonded, weld. The polished and etched sections always showed very favourable weld conditions, in which neither porosity nor slag inclusions could be observed. This type of weld does not, therefore, cause a reduction in the cross-sectional area of the longitudinal wire ; on the contrary, in a good welded joint of both wires, the material added by the transverse wire results in an increase in cross-sectional area or build-up.

Equally extensive series of tests have dealt with the effect of the welding heat on the strength within the weld area. Suitable sections were taken through the welded joints, by grinding, and the exact course of the tensile strength pattern mapped by hardness tests on the cross-sections of the longitudinal and transverse wires. The results show that the tensile strength of the longitudinal wire is not affected in any way by the presence of the weld area. Contrary to common assumption, there is also no reduction in strength in the weld area itself. In fact, a small increase in tensile strength was observed, due to favourable heat treatment of the raw material, caused by the welding process in conjunction with the steel composition of the wires used. The same results were obtained on all samples investigated.

These investigations were also supplemented by examinations of the structure of the weld areas, in which special attention was paid to the boundary layer between the weld and the parent metal. A series of photo-micrographs of an unalloyed 0·2 per cent C steel, taken in continuity at one weld in the longitudinal as well as in the transverse wire, showed the successive structural changes caused by the heat applied during the welding process and by the welding as such. The character of the structure closer to the weld area showed the gradual solution of perlite and ferrite by the increasing effect of heat. Thus, in the adjacent region a change in the structure could already be noted ; a zone could be recognised, marked by a characteristic transitional structure which continued into the weld area itself. The sorbitic, heat-treated structure of the weld area after electric resistance welding was very similar to the structure produced when steel wires are patented and which is considered particularly useful for this purpose. The short heating period in fully automatic electric resistance welding thus probably brings about the solution of the mixed ferrite-perlite structure, accompanied by a temporary formation of the γ-mixed crystal structure, but the solid solution stage is never exceeded and the state of fusion is not reached. This also explains the slag-free, gradual transition at the weld, which, therefore, did not show the sharply defined penetration zone characteristic of fusion welds. The small amounts of ferrite still remaining in the sorbite indicated that the fusion period was not sufficiently long to cause the mixed structure to dissolve completely, although the austenitic temperature had been reached.

Owing to the short period of overheating and the associated reduction in the number of crystals, a considerable amount of intermediate phase was nevertheless found, together with sorbite, on cooling. This occurred in the welding zone itself and in the region of maximum strength. Similar structural examinations were carried out on the weld areas of wires of equal, and alternatively of greatly different, diameters ; the changes in structure always resembled those described above.

If a weld area of this kind is tested in the usual manner in a static tensile test, the fracture always occurs outside the weld area, generally at a distance of 0·4 to 1·2 in. from it. The elastic limit, the elongation, and the tensile strength determined in this way correspond, therefore, to those of the longitudinal wires used. If the fracture occurs close to, or within, the weld area, it may be assumed that an incorrect welding technique has been employed or that wires of unsuitable steel have been used. In other words, the quality of the wire itself determines the quality of the structural steel mesh ; hence, all static calculations can be based on the stress-strain diagram of the wire (Fig. 1).

The behaviour of the weld area was also examined by a special test under conditions similar to those applying to a rod set in concrete. For this purpose the weld area was embedded in Wood's metal ; the longitudinal wire

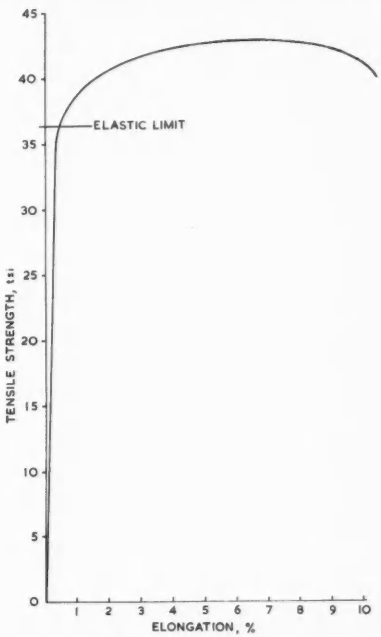


Fig. 1. **Stress-strain diagram of wire.**

was then withdrawn from the metal. The experiment showed that the welded joint of two wires of equal diameter has a greater tensile strength than the longitudinal wire, if the depth of penetration exceeds one tenth of the sum of both wire diameters. At a lower depth of penetration, the longitudinal wire can be pulled out and the welded joint shears, while at greater penetrations the longitudinal wire breaks.

By the use of suitable steels and by correct welding it is therefore possible not only to increase the quality of the manufactured steel wire mesh, but also to maintain a constant quality in continuous production. The mechanical properties which must be maintained in manufacture, as the minimum requirements, are :—

Elastic limit, 3170 to 3500 tsi.
Tensile strength, 3800 to 4130 tsi.
Elongation, 8 per cent measured on a long standard test bar.

In addition, the steel must pass the cold bending test (folding test) within one mesh width, with a bending angle of 180 deg.

CONSTRUCTION OF THE MACHINE

To produce, economically, a welded mesh from perpendicularly intersecting steel wires, certain mechanical and electrical features must be combined in a machine in such a way that fully automatic production at a sufficiently high output rate is obtained and that the metallurgical conditions previously mentioned are met.

The following sequence of individual functions must be provided for :—

(1) Supply of a considerable number of longitudinal wires. For the usual screen width of up to more than 78 in., often 50 or more longitudinal wires are required.
(2) Supply of the transverse wire in such a way that it runs perpendicularly to the longitudinal wire and makes contact with the latter at the required points.
(3) Clamping of every wire intersection between two electrodes through which the welding current and the necessary welding pressure are applied.
(4) Application of the welding current for an accurate length of time.
(5) Removal of the electrode pressure and release of the welded wires for transporting.
(6) Transport of the welded transverse wire, together with the longitudinal wires, over an accurately adjustable distance, so that the pitch of the next transverse wire on the longitudinal wires will be in accordance with the desired mesh width.

Electrical Features

The electrical arrangements are chiefly determined by the way in which the welding current is to be supplied to the wire intersections. Only low a.c. voltages, of about 1 to 4 V, are required for welding, but currents of the order of several thousand amperes are necessary. Welding times are mainly in the region of one tenth of a second or slightly longer. These short times are due, on the one hand, to the desire to increase the output of the machine and, on the other hand, to the fact that the previously mentioned metallurgical properties and high tensile strengths can be obtained only by short welding times in conjunction with suitable welding pressures. Longer welding periods cause undesirable annealing in the neighbourhood of the welded area, resulting in a significant lowering of the elastic limit and necessitating an additional expenditure of electrical energy which can be avoided in short welding times.

Electrical energy supplied by the mains is converted into low voltage energy at high current strength by means of a transformer, in all installations. This can be carried out in various ways, in one of which the energy is supplied at high voltage directly to the weld areas. The conversion into high current intensity is then carried out at this point by means of many individual transformers. In this method, known at the multi-transformer method, a large number of closely adjacent transformers, over the whole width of the machine, receives current from the mains supply through thin copper leads, at an only slightly changed voltage. Short electrodes, on which the longitudinal wires for the mesh rest, are screwed to the terminals which form the ends of the secondary windings. The transverse wire, in turn, rests on the longitudinal wires and the circuit is closed by " passive " electrodes (Fig. 2), so that series connection is made through two weld areas.

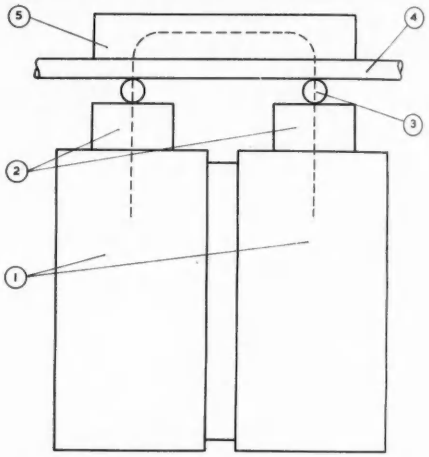


Fig. 2. **Path of welding current in the multi-transformer method.**
(1) Transformer ; (2) " active " electrodes ; (3) longitudinal wire; (4) transverse wire ; (5) " passive " electrodes.

Altogether, the welding current has a path length of only a few inches. With closer divisions of the transverse wires, several wire intersections can be welded with one transformer. On the other hand, only simple means are required to weld only one intersection with one transformer. The " passive " electrode requires no current supply ; it can therefore be removed without difficulty during the time required to transport the mesh to the next welding position. Cooling of the electrodes is unnecessary, as the heat losses are low.

In this method of welding a surprisingly small amount of electrical energy is consumed per weld. This also facilitates the control of the welding current and the conversion of the welding voltage.

The selection of the electrode material requires great care, since it is highly stressed as a result of the high temperatures and the electrode pressures, which frequently reach several hundred pounds per weld area. Cast materials are unsuitable because of their inherent porosity. On the other hand, forged electrolytic copper is suitable, while the best results are obtained with the usual electrode materials of copper-chrome or copper-silver-cadmium alloys. Although these alloys do not possess the high electrical conductivity of electrolytic copper, they have considerable strength at elevated temperatures and do not tend to form alloys with iron.

An accurate control for the welding time is essential to obtain consistently strong welded intersections in a wire mesh. Control by contactors or other electromagnetic switches is not possible for these short welding times, as their response times are too irregular. For this reason electronic timing valves and mechanically operating switches are used. In conjunction with

synchronous time-signal transmitters, ignitrons can switch outputs of the order of several hundred kilowatts with great chronological accuracy. Arcing and burning at the switch contacts are eliminated, but the valves have to be replaced from time to time.

A method which has been employed for a considerable period uses precision-driven mechanical switches which, by reason of their accurate manufacture and careful design, control the above-mentioned times within sufficiently close limits. The fully automatic mesh welding machine described here operates with this patented type of impulse timer, which, driven by a cam shaft, has a switching position for each transformer (Fig. 3). With the wire mesh in the welding position, the impulse timer proceeds to close and to open the switches in rapid succession. Burning at the switch contacts is relatively slight, even after considerable use; this can be accounted for by the favourable power factor of approximately 0·99 in the subsequent circuit and the moderate energy consumption of the multi-transformer system.

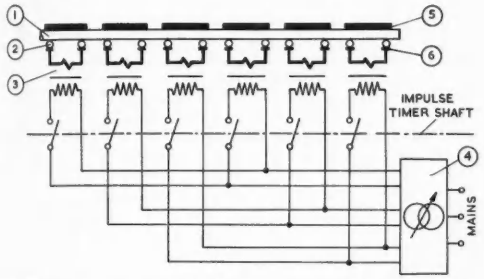


Fig. 3. **Energy supply in the multi-transformer method, with mechanical current impulse timer.**
(1) Transverse wire; (2) longitudinal wire; (3) welding transformer; (4) variable ratio transformer; (5) "passive" electrode; (6) "active" electrode.

The welding transformers are of particularly stable mechanical construction and are able to withstand great electrical overloads. They are so connected to the three mains phases that the load is balanced in time and phase. A variable-ratio transformer in a circuit designed to economise in plate current, which permits the selection of the correct voltage adjusted to the various wire gauges and speeds, is located between the mains and the welding transformers. The mains load amounts to approximately 75 kVA.

Mechanical Drive

A mesh welding machine must perform all necessary mechanical operations in a cycle time of 1 to 2 seconds if its capacity is to meet economic demands. The output is not solely determined by the number of welds made per second, but primarily by the time required for welding and for transporting, that is to say, by the number of transverse wires which can, in effect, be welded per hour. A rational sequence of the whole process in the short period of 1 to 2 seconds is made possible only by operations which are largely automatic. Every hand-controlled process was therefore eliminated as far as possible in the development of the structural steel mesh welding machine described in this article. The straightened transverse wires, cut to lengths, are automatically taken from a large container and arranged, and are then fed to the welding section at a speed corresponding to the transporting rate of the welded mesh.

The electrode contact required for the welding process requires high pressures, particularly when short welding times are employed. While for 2 mm wires a contact pressure of approximately 90 lb per intersection suffices, it is necessary to apply about 660 lb for 8 mm wires.

The required contact pressure is exerted by a loading beam, which runs across the machine and acts evenly on all electrodes. Thus, the total pressure can amount to several thousand pounds. The loading beam is operated either hydraulically, by compressed air, or mechanically, the mechanical method being preferred because of its lesser susceptibility to trouble and its lower cost.

In this construction, the "passive" electrodes, indicated schematically in Figs. 2 and 3, are spring-loaded and so arranged on a common beam as to be easily interchangeable. The pressure on the intersections can thus be set individually or as a whole. While the machine is running, the loading beam is raised and lowered by cams in sequence with the machine.

After welding, the mesh is advanced one pitch by means of hooks on a feed carrier, engaging with the transverse wire which has just been welded. The movement for this carrier is also derived from a cam and is infinitely variable from 2·0 to 13·1 in.

The machine is driven by one main motor, which actuates the transverse wire feed, the loading beam, the welding current, impulse timer, and mesh transport in the required order. A hydraulic, infinitely variable speed unit, placed after the motor, permits different operating speeds to be selected, to deal with from 10 to 50 transverse wires per minute.

Longitudinal wires from 5 mm gauge downwards are generally worked up directly from the coil. Just before reaching the welding section, the wires run through straightening rolls. They are then generally welded into screens of about 16 ft 5 in. to 26 ft 2 in. in length. It is, however, possible to produce larger screens. The completed screen is coiled on a drum, driven off the welding machine. The capacity of this drum is generally about 164 ft in the production of structural steel mesh. The completed screens are withdrawn from the side.

Wires above 5 mm gauge are individually inserted by hand as straightened longitudinal wires; a guide facilitates insertion. These types of wires are mostly welded into screens of certain definite sizes. To make the machine fully automatic, a mechanical feed for longitudinal wires was also developed for these straightened wires, by which the wires can be fed to the machine from large containers, for every required pitch.

While one screen is being welded, the wires for the next screen are being prepared at the accurately spaced pitch; they are then advanced immediately after completion of the previous screen. The desired pitch for the longitudinal wires is first set on a selector dial.

For completed screens of heavy wire, which are removed by hand, a release mechanism was constructed which ejects the completed screens and stacks them automatically on a trolley.

Owing to its automatic operation, the control of the machine is very simple:—

A suitable voltage, based on practical experience, is selected at the control panel, the longitudinal wires are fed to the machine at the required pitch, the pitch of the transverse wires is adjusted, and the motor and the welding current are switched on with the loading beam raised and the variable speed unit set to the no-load position. The machine is then set in motion at the desired speed by moving the gear lever and is stopped after a screen has been completed. The operator has time to replenish the supply of transverse wires while a screen is being welded. For the execution of large batches using the same wire diameter, an additional device can be employed to switch off the machine automatically after the last transverse wire has been welded. The number of transverse wires in a screen is preselected on a counter and the machine is stopped, by means of an electro-magnet, at the end of every screen. It is switched on again by hand. The standard model of this type of screen welding plant is designed for use with longitudinal wire pitches from about 2¼ in. upwards, in steps of from 2¼ to 11¾ in.

U. S. A.

High-Temperature Protection of Steel with Silicone-Aluminium Coatings

By A. E. Durkin and A. H. Horner. (From *Materials and Methods*, Vol. 38, No. 3, September, 1953, pp. 114-116, 9 illustrations.)

The correct use of aluminium-pigmented silicone coatings can help manufacturers of high temperature equipment to extend its life, and to cut costs of materials and fabrication. Tests show that silicone-aluminium paints will withstand any temperature condition where structural considerations permit the use of mild steel. The limiting factor of the mild steel-silicone system is the steel itself, not the coating. Thus, silicone-coated mild steel can be substituted for stainless steel in apparatus operating up to and including 1000° F. A silicone-aluminium coating can also lengthen the life of a mild steel part subjected to intermittent brief exposures to much higher temperatures.

The oxidation of stainless steel is quite different from the oxidation of mild steel. Mild steel continues to oxidise until it is completely destroyed. In stainless steel, an oxide is formed which acts as a protective barrier against further oxidation. Although the oxidation of stainless steel is not as critical as that of mild steel, there is considerable evidence to show that stainless steel parts need protection if they are to be used continuously in the 1400° to 1600° F temperature range.

Appreciable protection in this range is provided by silicone-aluminium coatings. Above 1600° F, discolouration of the coating occurs, but a minimum of oxidation results and there is little thinning out of the metal. In addition to preventing serious oxidation, silicone coatings on stainless steel have been effective in promoting better heat distribution by reducing local hot spots, and in preventing oxidation at welded areas in an assembly.

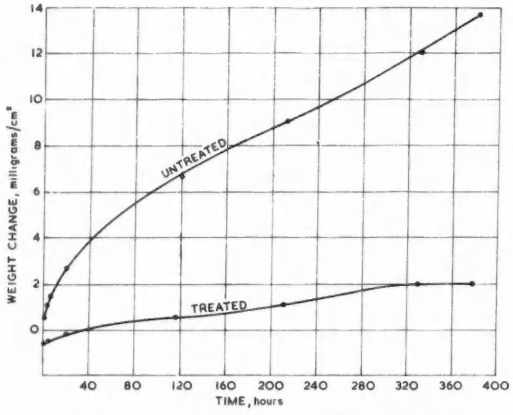


Fig. 1. **Comparison of oxidation of untreated and silicone-treated mild steel at 930° F.**

Mild steel, protected with a silicone-aluminium coating, can be used in temperature ranges where it would ordinarily have oxidised to failure. Oxidation curves for a temperature of 930° F for an untreated and a silicone treated steel are shown in Fig. 1. At the completion of the test, the untreated panel had increased in weight by 14 mg/cm² and was still gaining, whereas the protected panel had levelled off at 2 mg/cm². Similar tests have been run for 1000 hr, with no breakdown of the finish.

For temperatures over 1000° F, mild steel would not ordinarily be used. In some cases, however, it is possible that a part may operate over this range for short periods of time. In the case of a silicone-treated and

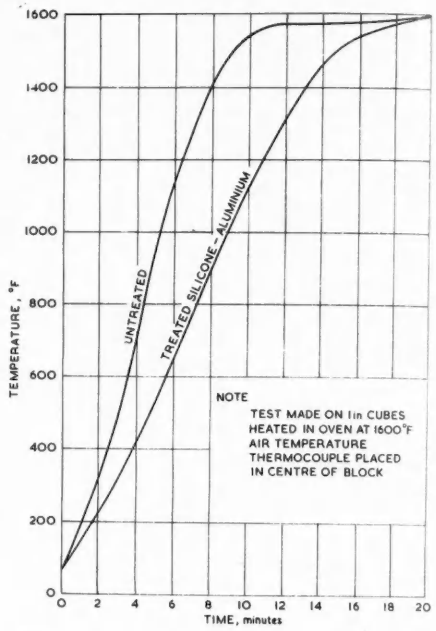


Fig. 2. **Effect of silicone-aluminium on the heating rate of mild steel.**

an untreated mild steel cylinder, both heated through 20 cycles at 1650° F, each cycle consisting of heating 2 minutes at temperature and cooling 1 minute by blasting with cold air, pitting of the untreated cylinder was evident.

Undoubtedly, one factor contributing to the protective value of the silicone coating is its heat transfer characteristics. The curves shown in Fig. 2 were obtained by placing sample blocks of steel in a furnace held at 1600° F, and recording the temperature rise. After 10 min, the untreated block had reached 1550° F and the silicone-treated block only 1095° F. Although the two curves reach the same level in about 20 min, the coating appears to offer an advantage for equipment to be operated at high temperatures for short time cycles.

On stainless steel, the protective value of a silicone-aluminium coating has been demonstrated. Treated and untreated panels of stainless steel were heated for 203 hr at 1600° F, 15 hr at 1700° F, and 15 hr at 1800° F. There was a considerable difference between the weight gains of the treated and untreated panels in the lower range, this difference beginning to disappear after about 180 hr. The oxides formed during this test were not disturbed. If they had been removed by thermal shock, as in some actual applications, the oxidation curve for the untreated steel would not have levelled out, but would have continued upwards as additional oxide was formed. Then the value of the silicone coating would have become more evident.

The life of other heat-resistant alloys can be similarly extended. In the case of untreated and silicone-coated Inconel at a temperature of 1400° F, the untreated Inconel reached its maximum oxidation—a weight gain

of 0·8 mg/cm²—after 8 hr. The silicone-treated Inconel reached its maximum oxidation in the same time interval but its average weight gain was only 0·5 mg/cm².

Many tests have been conducted on silicone-treated mild and stainless steels in an attempt to determine what phenomenon takes place when they are heated at high temperatures. No evidence of aluminium or silicone penetration has been discovered; however, there is no formation of scale. The protective film most likely is a complex oxide formation. However, diffusion will take place if the coating is subjected to a reducing atmosphere.

AUSTRIA

Semi-Graphical Method for the Study of Damped Three-Mass Systems

By W. KURZEMANN. (From *Maschinenbau und Wärmewirtschaft*, Vol. 8, No. 7, July, 1953, pp. 187-193, 7 illustrations.)

This article describes the use of vector diagrams for the study of forced vibration conditions of three-mass systems. The general applicability of this method will be illustrated in our next issue, with a numerical example relating to a nine-mass system. The procedure seems less laborious than the evaluation of frequency tables including damping and impressed forces.

VIBRATING systems can be investigated by means of vector diagrams, which visually express the equilibrium of forces acting at each mass of the system. For completeness, the three-mass system will first be treated analytically and then investigated by means of the graphical method.

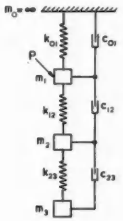


Fig. 1. **Three-mass system with damping proportional to velocity.**

ANALYTICAL TREATMENT.

The conditions of a three-mass system of the type shown in Fig. 1 can be expressed by means of the differential equations

$$\left.\begin{aligned} m_1\ddot{x}_1 + c_{01}\dot{x}_1 + c_{12}(\dot{x}_1 - \dot{x}_2) + k_{01}x_1 \\ + k_{12}(x_1 - x_2) = P_x, \\ m_2\ddot{x}_2 + c_{12}(\dot{x}_2 - \dot{x}_1) + c_{23}(\dot{x}_2 - \dot{x}_3) \\ + k_{12}(x_2 - x_1) + k_{23}(x_2 - x_3) = 0, \\ m_3\ddot{x}_3 + c_{23}(\dot{x}_3 - \dot{x}_2) + k_{23}(x_3 - x_2) = 0, \end{aligned}\right\} \quad (1)$$

where m_1, m_2, m_3 = masses, c_{01}, c_{12}, c_{23} = damping cofficients, and k_{01}, k_{12}, k_{23} = stiffnesses. Introducing the complex variables

$$\left.\begin{aligned} P_x = P_0\, e^{i\omega t}, \quad x_1 = \xi_1\, e^{i\omega t} \\ x_2 = \xi_2\, e^{i\omega t}, \quad x_3 = \xi_3\, e^{i\omega t} \end{aligned}\right\} \quad .. \quad (2)$$

eqs. (1) give, after grouping together the terms relating to each of the unknowns ξ_1, ξ_2, ξ_3,

$$\left.\begin{aligned} m\,\xi_1 - n\,\xi_2 = P_0 \\ -n\,\xi_1 + o\,\xi_2 - p\,\xi_3 = 0 \\ -p\,\xi_2 + q\,\xi_3 = 0 \end{aligned}\right\} \quad .. \quad .. \quad (3)$$

where :

$$\left.\begin{aligned} m &= -m_1\omega^2 + k_{01} + k_{12} + i\omega c_{01} + i\omega c_{12} \\ n &= k_{12} + i\omega c_{12} \\ o &= -m_2\omega^2 + k_{12} + k_{23} + i\omega c_{12} + i\omega c_{23} \\ p &= k_{23} + i\omega c_{23} \\ q &= -m_3\omega^2 + k_{23} + i\omega c_{23} \end{aligned}\right\} \quad (4)$$

The complex amplitudes are thus obtained from eqs. (3) as

$$\left.\begin{aligned} \xi_3 = (p/q)\,\xi_2, \quad \xi_2 = [n\,q/(q\,o - p^2)]\,\xi_1, \\ \text{and} \quad \xi_1 = P_0\,(o\,q - p^2)/[m\,(o\,q - p^2) - n^2\,q] \end{aligned}\right\} \quad (5)$$

These expressions are of the form

$$\xi = (A + i\,B)/(C + i\,D),$$

which can be represented in polar co-ordinates by the vectors

$$\left.\begin{aligned} \xi_1 = a_1\, e^{i\alpha} = a_1(\cos\alpha + i\sin\alpha), \\ \xi_2 = a_2\, e^{i\beta} = a_2(\cos\beta + i\sin\beta), \text{ and } \xi_3 = a_3\, e^{i\gamma}, \end{aligned}\right\} \quad (6)$$

so that their absolute values are given by

$$a = |\,\xi\,| = |\,(A + i\,B)/(C + i\,D)\,|$$
$$= |\,A + i\,B\,| \,/\, |\,C + i\,D\,| = \sqrt{A^2 + B^2}/\sqrt{C^2 + D^2}.$$

Furthermore, by substituting the values from eqs. (6) in eqs. (3), the components of the forces in equilibrium at each mass position are obtained. For instance, $-n\,\xi_1 + o\,\xi_2 + p\,\xi_3 = 0$ gives, for the components in the direction of P and perpendicular thereto, the equations :—

$$-k_{12}a_1\cos\alpha + \omega c_{12}a_1\sin\alpha - m_2\omega^2 a_2\cos\beta + k_{12}a_2\cos\beta + k_{23}a_2\cos\beta - \omega c_{12}a_2\sin\beta - \omega c_{23}a_2\sin\beta - k_{23}a_3\cos\gamma + \omega c_{23}a_3\sin\gamma = 0$$

and

$$-k_{12}a_1\sin\alpha - \omega c_{12}a_1\cos\alpha - m_2\omega^2 a_2\sin\beta + k_{12}a_2\sin\beta + k_{23}a_2\sin\beta + \omega c_{12}a_2\cos\beta + \omega c_{23}a_2\cos\beta - k_{23}a_3\sin\gamma - \omega c_{23}a_3\cos\gamma = 0.$$

Graphically, these relations are simply the projections of a polygon of forces in two directions.

VECTOR-DIAGRAM METHOD

The method for determining forced-vibration conditions of three-mass systems by means of vector

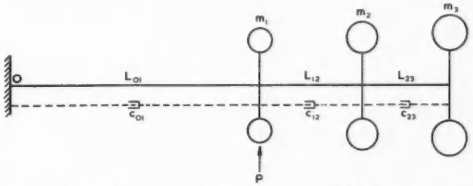


Fig. 2. **The three-mass system investigated in the numerical example.**

diagrams will be explained by considering its application to the particular system illustrated in Fig. 2. The constants of the system are as follows :—

Polar moment of inertia of shaft cross-section :
$$\mathcal{J}_p = 602\ \text{cm}^4.$$

Reference radius of gyration :
$$r_{red} = 10\ \text{cm (for all masses).}$$

System constant : $H = G\,\mathcal{J}_p/r^2_{red} = 5 \times 10^6$ kg.

Equivalent shaft lengths :

$L_{01} = 111$, $L_{12} = 35$, $L_{23} = 25$ cm.

Shaft stiffnesses (from $k = H/L$) :

$k_{01} = 0{\cdot}045 \times 10^6$, $k_{12} = 0{\cdot}143 \times 10^6$,

$k_{23} = 0{\cdot}2 \times 10^6$ kg/cm.

Masses : $m_1 = 6$, $m_2 = 10$, $m_3 = 15$ kg sec^2/cm.

Damping ratio : $\psi = 0{\cdot}75 = 2\,\pi/M^*$ (where M^* = dynamic magnifier of each sub-system).

It will be recalled from a previous article on two-mass systems† that the relation between ψ and the damping coefficient c is :

$$\psi = \pi\, c\, \omega_n\, a^2/(k\, a^2/2) = 2\,\pi\, c\, \omega_n/k = 4\,\pi\,\gamma = 2\,\pi/M^*.$$

Furthermore, use will be made of the frequency ratios

$$\nu_1 = \omega/\omega_{n1} \quad \text{and} \quad \nu_3 = \omega/\omega_{n3},$$

where $\omega_{n1}^2 = k_{12}/m_1$ and $\omega_{n3}^2 = k_{23}/m_3$.

In the above expressions, ω is the forced phase velocity of the system. For the present example $\omega_{n1} = 154{\cdot}2$ rad/sec and $\omega_{n3} = 115{\cdot}3$ rad/sec. The vector diagrams in Fig. 3 for the three individual masses are shown for the frequency ratio $\nu_3 = \sqrt{1{\cdot}5}$.

Vector diagram for mass m_3 : To obtain diagrams in non-dimensional quantities, the amplitudes are divided by a_3 and the forces by $k_{23}\, a_3$. All vectors will be indicated in bold type. Fig. 3a for mass m_3 is constructed as follows :

(1) Plot $\overrightarrow{O_3 A} = \mathbf{a}_3/a_3 = 1$ as a vector on the horizontal base line.

(2) Since " hysteresis damping " (or damping in shaft material) is assumed, calculate $\tan \delta_{23} = \psi/2\pi = 0{\cdot}75/2\,\pi = 0{\cdot}1195$ and erect a vector $\overrightarrow{A D}$ of this length, perpendicularly to $\overrightarrow{O_3 A}$.††

(3) Extend the line $\overrightarrow{O_3 A}$ to point B, so that $|\overrightarrow{O_3 B}| = \nu_3^2 = 1{\cdot}5$.

(4) Draw line $\overrightarrow{O_3 D}$ and extend it beyond point D. From point B, drop a perpendicular on the extended line of $\overrightarrow{O_3 D}$, so as to intersect the latter at a point C.

Then $O_3 AC$ is the vector triangle for the relative vibration amplitudes of masses m_3 and m_2, with

$$\overrightarrow{O_3 A} = \mathbf{a}_3/a_3,\ \overrightarrow{AC} = -\mathbf{a}_2/a_3,\ \overrightarrow{O_3 C} = \mathbf{s}_{32}/a_3 = (\mathbf{a}_3 - \mathbf{a}_2)/a_3$$

giving $|\overrightarrow{AC}| = 0{\cdot}515$. The triangle of the inertia force $\mathbf{X}_3$, spring force $\mathbf{S}_3$, and damping force $\mathbf{D}_3$ acting at mass m_3 is $O_3\, BC$, since :

$$\mathbf{X}_3 = \overrightarrow{O_3 B} = \nu_3^2 = m_3\, \omega^2\, \mathbf{a}_3/k_{23}\, a_3,$$

$$\mathbf{S}_3 = \overrightarrow{O_3 C} = \mathbf{s}_{32}\, k_{23}/k_{23}\, a_3, \text{ and}$$

$$\mathbf{D}_3 = \overrightarrow{BC} = \omega\, c_{32}\, \mathbf{s}_{32}/k_{23}\, a_3.$$

Vector diagram of mass m_2 : For clarity, this diagram is drawn in three stages (Fig. 3b). The first triangle $O_2 GI$ is the triangle CAO_3, redrawn with vectors in opposite directions. It gives $\overrightarrow{O_2 G} = +\,\mathbf{a}_2/a_3$ of length 0·515, and $\overrightarrow{GI} = -\,\mathbf{a}_3/a_3$ of unit length.

The second construction of Fig. 3b serves to determine the forces, in the first place those due to the connections of mass m_2 with mass m_3. The triangle $O_2 K\mathcal{J}$ is triangle $O_3 CB$, and it gives :—

Spring force $\mathbf{S}_{23} = \overrightarrow{O_2 K} = \mathbf{s}_{23}\, k_{23}/k_{23}\, a_3$ (with $\mathbf{s}_{23} = \mathbf{a}_2 - \mathbf{a}_3$),

damping force $\mathbf{D}_{23} = \overrightarrow{K\mathcal{J}} = c_{23}\, \mathbf{s}_{23}/k_{23}\, a_3$, and

inertia force $\mathbf{X}_{23} = \mathbf{S}_{23} + \mathbf{D}_{23} = \overrightarrow{O_2 \mathcal{J}}$ of length 1·5

The next step is to draw the inertia force of m_2, which is

$$\mathbf{X}_2 = \overrightarrow{\mathcal{J} L} = m_2\, \mathbf{a}_2\, \omega^2/k_{23}\, a_3 = (m_2\, \mathbf{a}_2/m_3\, a_3) \times \nu_3^2$$

of length 0·516 in the direction of $\mathbf{a}_2/a_3$, that is, parallel to $\overrightarrow{O_2 G}$.

The vector sum $\mathbf{X}_2 + \mathbf{X}_3$ must be in equilibrium with the forces due to the connection with mass m_1, i.e.,

Spring force $\mathbf{S}_{21} = \mathbf{s}_{21}\, k_{12}/a_3\, k_{23} = \overrightarrow{MO_2} = \overrightarrow{O_2 Q}$, and

damping force $\mathbf{D}_{21} = c_{12}\, \omega\, \mathbf{s}_{21}/a_3\, k_{23} = \overrightarrow{LM} = \overrightarrow{QN}$,

The procedure for obtaining these is as follows :

(1) Evaluate

$$\begin{aligned}\tan \delta_{21} &= D_{21}/S_{21} = c_{12}\, \omega\, s_{21}/k_{12}\, s_{21} \\ &= (c_{12}/c_{23}) \times (k_{23}/k_{12}) \times (c_{23}/k_{23}) \times \omega \\ &= (c_{12}/c_{23}) \times (k_{23}/k_{12}) \tan \delta_{23}\ ;\end{aligned}$$

(2) Draw line $\overrightarrow{O_2 M} = -\,\mathbf{S}_{21}$, which forms the angle δ_{21} with $O_2 L$;

(3) Join $\overrightarrow{LM} = \mathbf{D}_{21}$, perpendicular to $\overrightarrow{O_2 M}$. (The triangle $O_2 NQ$ on the left-hand side of O_2 is the equivalent of $O_2 ML$).

To complete the amplitudes diagram (begun with $O_2 GI$), it is necessary to determine the relative displacement between m_2 and m_1, which is

$$\mathbf{s}_{12}/a_3 = \frac{\mathbf{s}_{21}\, k_{12}}{a_3\, k_{23}} \times \frac{k_{23}}{k_{12}} = \frac{\mathbf{S}_{21}}{k_{23}\, a_3} \times \frac{k_{23}}{k_{12}}$$

$$= \overrightarrow{MO_2} \times \frac{k_{23}}{k_{12}} = \overrightarrow{O_2 H}.$$

Thus, $\overrightarrow{O_2 H}$ is drawn from point O_2, in the direction parallel to $\overrightarrow{O_3 M}$. Finally, by joining points G and H, the amplitude of mass m_1 is obtained as

$$-\,\mathbf{a}_1/a_3 = \overrightarrow{GH}.$$

Vector diagram for mass m_1 : The conditions will first be considered for the case where the system shown in Fig. 2 ends at mass m_1 (so that $L_{01} = 0$). The amplitudes triangle in Fig. 3c is $O_1 RS$, which is HGO_2 drawn with its vectors in reversed directions.

The force vectors are compounded as follows : Draw triangle $O_1\, Q'\, T$, which is $O_2\, M\, L$ with its vectors reversed in direction. This gives the forces on mass m_1 which are due to its connection with mass m_2, *viz.* : $\mathbf{S}_{12} = O_1 \overrightarrow{Q'}$, $\mathbf{D}_{12} = \overrightarrow{Q' T} = -\,\overrightarrow{NQ}$, and $O_1 \overrightarrow{T} = \mathbf{S}_{12} + \mathbf{D}_{12} = \mathbf{X}_1 + \mathbf{X}_2$, the latter term representing the reaction of the system on mass m_1. The inertia force of mass m_1 is

$$\mathbf{X}_1 = m_1\, \omega^2\, \mathbf{a}_1/k_{23}\, a_3 = \frac{m_1}{m_3} \times \frac{\mathbf{a}_1}{a_3} \times \nu_3^2 = \overrightarrow{TU},$$

since $\nu_3^2 = \omega^2\, m_3/k_3$. $\mathbf{X}_1$ is drawn from point T in a direction parallel to $\mathbf{a}_1/a_3$.

Finally, the impressed force (also divided by $k_{23}\, a_3$ to obtain a non-dimensional quantity) is

$$\mathbf{P} = \mathbf{P}_0/k_{23}\, a_3 = \overrightarrow{UO_1}$$

and this vector completes the triangle $O_1 TU$.

$P_0/k_{23} = a_{3(st)}$ is the static deflection of spring k_{23} under the load P_0. Therefore,

$$M = k_{23}\, a_3/P_0 = a_3/a_{3(st)} = 1/|UO_1|$$

is the required dynamic magnifier for the forced frequency corresponding to the ratio $\omega^2/(k_{23}/m_3) = \nu_3^2 = 1{\cdot}5$. As a_3 has been chosen of unit length, $1/|UO_1|$ gives

†*The Engineers' Digest*, March, 1953, pp. 78-80.

††For " mass damping," $\tan \delta_{23} = c_{23}\, \omega/k_{23} = \nu_3/M_3 = \nu_3/(\psi/2\pi)$.

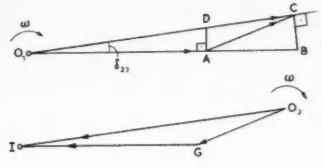


Fig. 3a.

$O_3A = \mathbf{a}_3/a_3 = 1$ $\quad O_3B = \nu_3^2 = \mathbf{X}_3 = 1{\cdot}5$
$AC = -\mathbf{a}_2/a_3 = 0{\cdot}515$ $\quad O_3C = \mathbf{S}_{32}$
$O_3C = (\mathbf{a}_3 - \mathbf{a}_2)/a_3 = \mathbf{s}_{32}/a_3$ $\quad BC = \mathbf{D}_{32}$

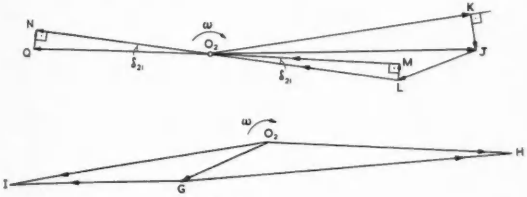


Fig. 3b.

$O_2K = \mathbf{S}_{23}$ $\quad LM = \mathbf{D}_{21}$
$KJ = \mathbf{D}_{23}$ $\quad O_2G = +\mathbf{a}_2/a_3$
$O_2J = \mathbf{X}_{23}$ $\quad GI = -\mathbf{a}_3/a_3$
$JL = \mathbf{X}_2$ $\quad O_2H = (\mathbf{a}_2 - \mathbf{a}_1)/a_3 = \mathbf{s}_{21}/a_3$
$MO_2 = \mathbf{S}_{21}$ $\quad GH = -\mathbf{a}_1/a_3$

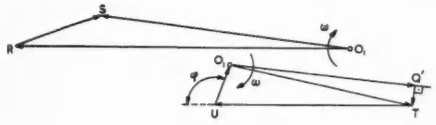


Fig. 3c.

$O_1R = \mathbf{a}_1/a_3$ $\quad Q'T = \mathbf{D}_{12}$
$RS = -\mathbf{a}_2/a_3$ $\quad O_1T = \mathbf{X}_1 + \mathbf{X}_2 = \mathbf{D}_{12} + \mathbf{S}_{12}$
$SO_1 = \mathbf{s}_{12}/a_3$ $\quad TU = \mathbf{X}_1$
$O_1Q' = \mathbf{S}_{12}$ $\quad UO_1 = \mathbf{P}_0/k_{23}\,a_3 = 1/M$

the numerical value of the dynamic magnifier directly.

The numerical evaluation yields the following values:

$OA = 1$; $OB = 1{\cdot}5$; $AD = 1/M_{23} = 0{\cdot}1195$; $AD = \tan\delta_{23}$; $BL = 0{\cdot}667 \times 0{\cdot}515 \times 1{\cdot}5 = 0{\cdot}515$ (where $m_2/m_3 = 0{\cdot}667$); $\tan\delta_{12} = \tan\delta_{23}$; $OM \times k_{23}/k_{12} = 1{\cdot}07 \times 7/5 = 1{\cdot}43 = OH$; $LU = 0{\cdot}4 \times 1{\cdot}92 \times 1{\cdot}5 = 1{\cdot}148$ (where $m_1/m_3 = 0{\cdot}4$, and $a_1/a_3 = 1{\cdot}92$) ; with the results :

$AC = -0{\cdot}515 = -a_2/a_3 = OG$;
$OH = 1{\cdot}43 = s_{21}/a_3$; $GH = -1{\cdot}92 = -a_1/a_3$;
$UO = 0{\cdot}272 = 1/M$; $M = 3{\cdot}68$;
$\varphi = 122°$ (angle between P_0 and a_1).

For the *complete system* given in Fig. 2, including the stiffness of the shaft L_{01} which is clamped to an infinite mass, the spring force k_{01} (of L_{01}) must be taken into account.

The construction is similar to that of Fig. 3c, but instead of $\mathbf{X}_1 = m_1\,\omega^2\,\mathbf{a}_1/k_{23}\,a_3 = \overrightarrow{TU}$ (or $\overrightarrow{LU}$), the vector to be used is

$$\overrightarrow{LU'} = \mathbf{X}_1 - (k_{01}\,\mathbf{a}_1/k_{23}\,a_3) = \overrightarrow{LU} = \overrightarrow{UU'}$$

as shown in Fig. 4. The evaluation gives

$$LU' = 1{\cdot}148 - 1{\cdot}92 \times 0{\cdot}225 = 0{\cdot}716.$$

Therefore, $U'O = 0{\cdot}38 = P_0/k_{32}\,a_3 = 1/M$, and $M = 2{\cdot}64$.

Furthermore, the damping force

$$\mathbf{D}_{10} = c_{10}\,\omega\,\mathbf{a}_1/k_{23}\,a_3,$$

which is 90 deg. ahead of $\mathbf{a}_1/a_3$, may also be taken into account, since the phase angle of damping δ_{10} is obtained from

$$\tan\delta_{10} = D_{10}/S_{10} = c_{10}\,a_1\,\omega/a_1\,k_{10} = c_{10}\,\omega/k = 1/M^* = \psi/2\pi = 0{\cdot}7/2\pi = 0{\cdot}1195.$$

The Resonance Function

The dynamic magnifier $M = a_3/a_{3(st)}$ can be calculated for various values of $\nu_3^2 = \omega^2/(k_{23}/m_3)$ (where ω is the phase velocity of the impressed force), and the plot of M against ν_3 gives the resonance curve. M is, therefore, the resonance function of the system.

As, with small damping coefficients, the phase angles δ due to damping are very small, it is sometimes necessary to calculate the sine and cosine projections of the vectors separately. The positions of the resonance peaks are determined very rapidly by first constructing diagrams for the undamped system (so that in Fig. 3, for instance, $\overrightarrow{BC} = \overrightarrow{KJ} = \overrightarrow{LM} = \overrightarrow{Q'T} = 0$). The correct flank and peak values are then determined by means of the diagrams for the damped system.

Energy Balance

It is of interest to note that the diagram in Fig. 4 can be used to determine the energy balance of the system.

The work input of the force P, per vibration cycle, is

$$W_{(P)} = \pi\,P\,a_1 \sin\varphi = \pi\,k_{23}\,a_2^2\,\frac{P}{k_{23}\,a_3}\sin\varphi\,\frac{a_1}{a_3}$$
$$= \pi\,k_{23}\,a_3^2 \times 2 \times (OGUH),$$

where $(OGUH)$ = area of quadrilateral $OGUH$. This can be subdivided into triangles (see Fig. 4) :

$$(OGUH) = (OGL) + (OLH) = (OBC) + (OLH)$$

since $GH \parallel UL$, $OG \parallel BL \parallel AC$ and $OG = AC$ (the symbol $\parallel$ means "parallel to").

The energy dissipated by damping between m_1 and m_2 is

$$W_{12} = \pi\,c_{12}\,\omega\,s_{12}^2 = \pi\,k_{23}\,a_3^2 \times \frac{c_{12}\,s_{12}}{k_{23}\,a_3} \times \frac{s_{12}}{a_3}$$
$$= \pi\,k_{23}\,a_3^2 \times 2 \times (OLH),$$

and the energy dissipated by damping between m_2 and m_3 is

$$W_{23} = \pi\,c_{23}\,\omega\,s_{23}^2 = \pi\,k_{23}\,a_3^2 \times \frac{c_{23}\,s_{23}}{k_{23}\,a_3} \times \frac{s_{23}}{a_3}$$
$$= \pi\,k_{23}\,a_3^2 \times 2 \times (OBC).$$

Energy equilibrium requires that

$$W_{(P)} = W_{12} + W_{23}$$

and this is so, since $(OGUH) = (OLH) + (OBC)$.

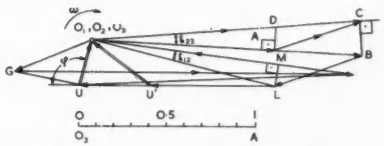


Fig. 4. **Complete diagram for three-mass system with impressed force and damping.**

The vector-diagram method is particularly suitable where the damping factors are of considerable influence, as in systems fitted with vibration dampers. It has been successfully applied to numerous types of multi-mass systems for the investigation of torsional vibration (engines), and linear and flexural vibrations (instruments, mountings, etc.).

Electric Spark-Hardening of Tools

By L. Y. Popilov. (From *Stanki i Instrument*, No. 5, 1953, pp. 17-19, 2 illustrations.)

Among new production processes, electric spark hardening deserves greater attention. The theoretical concepts underlying this process are as yet incomplete and often oblige the use of purely empirical procedures.

Electric spark hardening, also known as electric hardening, is a process which consists of applying an electrical impulse discharge to the surface of a steel cutting tool. As a result, the tool acquires an increased hardness and wear resistance. The energy required for the impulse discharge can be obtained *viz* the simple electrical circuit shown in Fig. 1.

The tool so treated constitutes one of the electrodes, the second electrode being a metal or carbon rod, called the hardening electrode. When the two electrodes are gradually brought into contact, an electrical discharge occurs on separation. The duration of this discharge depends on the properties of the circuit and usually does not exceed some 40 to 50 micro-seconds. Despite this very short time interval, the metal, in a region surrounding the point of the discharge, has time to become heated to a temperature of several thousand degrees and to cool down equally quickly. This leads to profound physical and chemical changes in a thin surface layer and thus brings about the hardening effect. By traversing the surface of the treated surface with the hardening electrode, it is possible to obtain a hardened layer over any desired region.

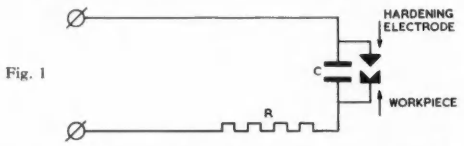


Fig. 1

In practice, electric hardening is usually carried out with specially designed apparatus based on the fundamental circuit shown in Fig. 1. There is no general agreement on the choice of optimum parameters for electric hardening circuits and equipment.

A critical examination of information obtained from a variety of sources has led to the following conclusions, which should be regarded as a basis for further research and practical analysis :—

(1) Electric spark hardening is a method of modifying the properties of the surface of ferrous alloys through thermo-chemical processes arising as a result of an impulse discharge through contact or through the breakdown of a spark gap.

(2) The basic phenomenon which causes the hardening effect of the steel surface is a highly localised and very sudden generation of heat. This high heat concentration, of microscopic volume, leads to the following :—

(a) High-speed quenching of metal fused by the discharge and its hardening in the form of meta-stable austenite.

(b) Dissolution of nitrogen from the air in the fused metal and the formation of solid nitrides, precipitated in a dispersed state in the mass of austenite.

(c) Dissolution of carbon from the hardening electrode in the fused metal and the formation of martensite and of hard carbides, also subject to disperse precipitation in the mass of austenite.

(d) Dissolution of various elements from the hardening electrode in the fused metal, leading to the alloying of the austenite layer formed.

(3) The following phenomena take place when existing techniques are applied, but are less recurrent as active factors :

(a) Transfer of elements between the electrodes of the spark gap.

(b) Transfer of metal by contact between the hardening electrode and the hardened surface.

(4) The basic factors in the process determining the results of spark hardening are :

(a) The electric parameters (voltage between electrodes, current, condenser capacity, duration and form of impulses, current density, and equivalent energy and power of the discharge).

(b) The mechanical parameters (pressure and relative velocity of motion of the hardening electrode).

(c) Physical and chemical parameters (chemical composition and physical properties of the materials of both electrodes, and the nature of the medium surrounding the electrodes).

(5) A statistical study of available data permits the setting up of preliminary standards applicable to

Table I. Conditions of Operation

Type of Treatment	Energy of Discharge W sec	Allowable limits		
		Voltage V	Capacitance μF	Short-circuit current A
Soft	0·05–0·1	25–50	10–20	0·25–0·5
Medium	0·1–0·5	50–80	20–60	0·5–1·0
Hard	0·5–1·0	80–120	60–100	1·0–2·5
Extra hard	1·0–4·0	100–120	100–300	2·5–4·0

Table II. Materials for Hardening Electrodes

Type of tool treated	Material of tool		
	Carbon steel	High speed steel	Carbide
	Material of hardening electrode		
For rough machining of medium and hard steels	*Ca, FC*	*Ca, FC*	*EG*
For rough machining of tough steels	*Ca, FC*	*EG*	*EG*
For finish machining (including thread cutting	*EG*	*EG*	*EG*

Ca = Carbides of tongsten-bearing and titanium-bearing types.
FC = Ferro-chrome.
EG = Electro-graphite with low ash content.

Table III. Properties of the Hardened Layer

Type of operation	Material		Thickness of layer mm		Hardness Rockwell C		Class of surface smoothness
	Tool	Electrode	Top	Intermediate	Top	Intermediate	
Soft	carbon steel	*Ca*	5–10	2–8	60–62	55–58	5–7
		EG	3–5	3–5	62–64	53–56	6–7
	HS steel	*Ca*	3–8	3–10	62–64	60–62	5–7
		EG	2–4	4–12	62–65	58–60	6–7
Medium	carbon steel	*Ca*	10–30	10–15	62–64	55–57	4–6
		EG	5–15	10–20	62–66	52–55	5–6
	HS steel	*Ca*	8–25	10–15	64–66	60–62	4–6
		EG	4–20	12–25	64–68	56–60	5–6
Hard	carbon steel	*Ca*	30–70	15–30	63–65	55–57	4–5
		EG	15–40	15–50	62–66	54–56	4–6
	HS steel	*Ca*	26–66	10–15	64–68	59–63	4–5
		EG	10–35	15–30	64–70	54–58	4–6

TABLE IV. CRITERION OF EFFECTIVENESS OF ELECTRIC SPARK HARDENING

Type of tool	Nature of Machined Material	Value of Criterion	
		Rough machining	Finish machining
Turning tools	Hard	1·4–1·6	1·3–1·5
	Tough	1·3–1·5	1·2–1·3
Milling cutters	Hard	1·4–1·6	1·25–1·45
	Tough	1·3–1·5	1·2–1·3
Drills	Hard	1·26–1·4	1·2–1·3
	Tough	1·15–1·25	1·5–1·2
Chisels	Hard	1·3–1·9	—
	Tough	1·5–2·5	—
Press tools	—	1·5–2·5	—
Counterboring cutters	—	—	1·25–1·4

manually performed electric spark hardening. These are summarised in Table I.

(6) Recommendations for electrode materials for this work are summarised in Table II.

(7) Under the operating conditions given in Table I, the type of current used for spark hardening (d.c., a.c., pulsating) is virtually immaterial.

(8) The most probable values of the properties of the hardened layer can be assumed to correspond with those given in Table III.

As a standard criterion of effectiveness of electric spark hardening, it is customary to determine the ratio between the time between regrinds of a hardened and an untreated tool, keeping the same feeds and speeds and using the identical measure of wear. Values of this criterion of quality found in practice are given in Table IV.

The principal requirements at present for the further advance of this method of increasing the productive capacity of tools, is the standardisation of equipment, its manufacture by a centralised source, and the creation of designs which eliminate the uncertainties associated with the purely manual treatment currently used.

ITALY

Fatigue Testing of Wire Ropes

By U. ROSSETTI. (From *L'Ingegnere*, Vol. 27, No. 7, July, 1953, pp. 769-771, 7 *illustrations.*)

The apparatus described in this article can be used for standard fatigue strength tests, as well as for the determination of the effects of different types of dynamic load conditions.

IT is frequently observed that flexible wire ropes with substantially similar static characteristics show marked differences in behaviour in actual service. The usual static investigations, in which the wires are tested under tensile, torsional, bending, and rupturing loads, give little information on the fatigue strength and probable life of wire ropes.

This is not surprising, in view of the complex types of dynamic loads that such ropes are required to sustain in practice. It would be desirable therefore, to be able to investigate much more thoroughly than hitherto the effects of various loading conditions on the fatigue strength of ropes. Static data are necessary, but are not sufficient in themselves to guarantee the strength of a wire rope under working conditions.

The importance of dynamic tests was appreciated long ago with regard to mechanical components, i.e., engine and machinery parts. It is a recognised procedure to subject such components to fatigue tests and to take account of the dynamic properties thus determined. Fatigue tests have led to improvements in construction and have made it possible to assess the probable life of an element more accurately than previously. For wire ropes, it should be possible to determine from dynamic data the most suitable sheave diameters for different rope types.

Experimental work along these lines is already being carried out in the United States, Great Britain, and Germany. In Italy, research work in this field has been initiated, the objects of this work being as follows :— (1) To establish more accurate data on the strength of flexible wire ropes ; (2) to solve specific problems propounded by rope manufacturers and users ; and (3) to develop an easy and rapid standard test procedure for determining the quality and strength of ropes, in addition to the standard static tests currently effected.

DESCRIPTION OF FATIGUE-TESTING APPARATUS.

A sketch of the apparatus developed for fatigue tests in bending and tension is shown in Fig. 1. The portal-type frame is erected on a suitable base-plate. A large driving sheave is mounted on the horizontal member in the upper part of the apparatus. The wire rope is laid over this sheave and also passes around a second sheave (or sheave assembly) situated at a lower level. This

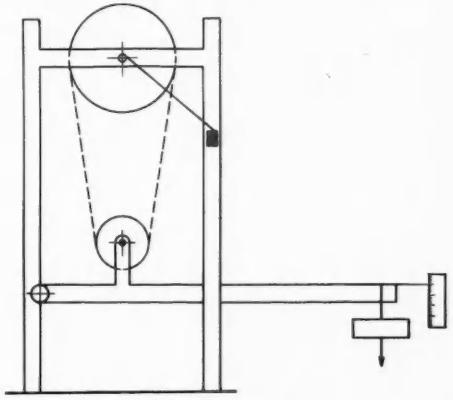


Fig. 1. **Fatigue-testing apparatus with sheaves having an alternating motion.**

second sheave is mounted on a long horizontal beam, designed as a loading lever and supported at one end by a pivot arrangement on one of the upright members. The other end of the beam carries the load and its deflection is indicated by a pointer on a vertical scale. Owing to the lever arrangement, the load on the rope is several times greater than the applied load at the free end of the beam. The load alternation frequency is about 50 to 60 cycles per minute and tests can be continued until rupture occurs.

In order to determine the fatigue strength values of a wire rope under various conditions, the lower sheave of the apparatus can be replaced by assemblies with two or three sheaves, as shown in Figs. 2 and 3. The two-sheave assembly allows the rope to be tested with 90-degree angles. The three-sheave assembly provides two possible test arrangements, *viz.*: Three angles, each of about 120 deg, and two angles of about 90 deg with a third (re-entrant) angle of about 4 deg over the small sheave at the centre of the assembly.

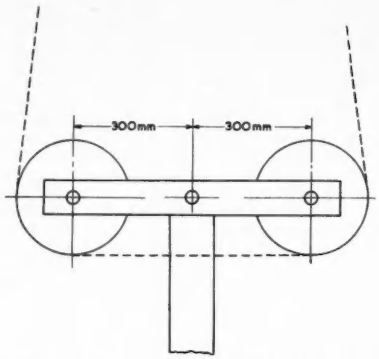


Fig. 2. **Two-sheave arrangement, with 90-degree angles.**

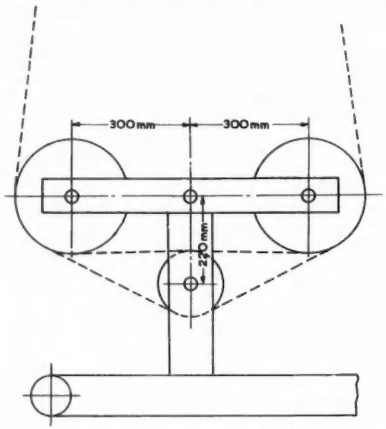


Fig. 3. **Three-sheave assembly, providing two possible test arrangements.**

Test Results.

Single-sheave arrangement: The first systematic series of tests was made with the single-sheave arrangement on the loading lever. Comparative tests were carried out on seven types of flexible wire ropes, all of 12 mm diameter, using a constant load of 1500 kg, which is between 1/5th and 1/7th of the breaking load for ropes of this size. Each type of rope was tested on sheaves of diameters equal to 20, 25, and 30 times the rope diameter.

The results showed very considerable differences in behaviour as regards fatigue strength. In particular, two ropes of German manufacture (constructed with two or more layers of strands locked by the Seale system, so that the strands remain strictly parallel) reached extremely high values of fatigue strength, as compared with other ropes of more conventional type. It was also found that ropes made of strands arranged around seven hemp centres are less efficient than ropes with a single fibre core. Finally, the fatigue tests clearly indicated the limitations of the usual static tensile and rupture tests.

Table I. Flexible Wire Ropes Subjected to Fatigue Tests. Load 1500 kg.

Rope No.	Type	Designation	Breaking load, kg	Safety factor
1	144 wires (6 × 24) + 7	UNI-1515	7700	1/5·1
2	222 wires (6 × 37) + 1	UNI-1509	8000	1/5·3
3	239 wires	S-239	10900	1/7·2
4	160 wires	A-160	9400	1/6·3

Multi-sheave arrangements: Four of the seven types of rope previously investigated were subsequently tested also with the multiple-sheave assembly. To avoid introducing additional variables, all other test conditions were left unchanged.

The rope data are given in Table I, and the test results in Table II, which includes figures for single, two- and three-sheave tests.

Table II. Results of Fatigue Tests.

Test system	Life of rope in number of cycles			
	UNI-1515	UNI-1509	S-239	A-160
Single sheave :—				
250 mm dia.	17800	26550	55020	129470
300 mm ,,	23480	50222	83570	198190
380 mm ,,	24020	51706	141100	472000*
Three sheaves with re-entrant angle	2704	7675	18675	18800*
Two sheaves	—	—	52000	64000

*Mean value of two test results.

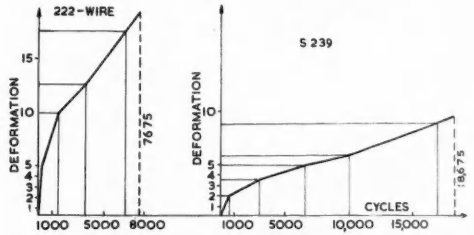


Fig. 4. **Curves showing deformation plotted against number of loading cycles for 222-wire fibre-core rope and for steel-core rope S-239. Tests on three-sheave assembly with re-entrant angle.**

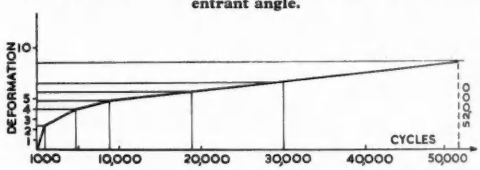


Fig. 5. **Curves of deformation plotted against loading cycles for rope S-239, tested on two-sheave assembly with 90-deg angles.**

The test data are also represented graphically in Figs. 4 and 5, which show curves of deformation and final rupture plotted against the number of load cycles. Their examination leads to some interesting conclusions, *viz.*:—

(i) High life values are obtained for especially well-manufactured wire ropes with wires of different diameters, arranged so as to avoid any possibility of overlapping of the strands. Additional tests with Seale-type ropes of Italian manufacture still have to be carried out, and these should show less divergences than the German ropes investigated.

(ii) The time-deformation curves are also different in each class of ropes considered, although the differences are smaller for the German steel-core ropes than for the six-strand ropes with hemp centres.

(iii) Rupture produced by fatigue, in the case of wire ropes with fibre cores, is characterised by extensive damage to strands and wires throughout the length of cable tested. For ropes with a steel core, the fatigue rupture is generally the result of a complete failure of the cable, with a clear and well-localised fracture. This may be due to a more uniform stress distribution in the latter types of rope, as a result of their special construction, so that failure occurs simultaneously throughout a cross-section.

(*Concluded on page* 444)

Automatic Extraction Steam Turbines in Czechoslovakia

By J. NEVOLE and F. MICHELE, and J. MAYER. (From *Strojírenství*, Vol. 2, No. 10, 1952, pp. 454-465, 14 illustrations.)

In our September issue, we described the design of large Czech steam turbines manufactured by the Lenin works, Pilsen, and the CKD-Stalingrad works, Prague, while details were given last month of pass-out and back-pressure turbines from the Lenin works, with special emphasis on their governing systems. We conclude this series with descriptions of single and double automatic pass-out turbines, and their governing systems, from the Klement Gottwald works, Brno. In addition, indications (by J. Mayer) are given of a system of governing pass-out turbines.

CONDENSING TURBINES WITH SINGLE AUTOMATIC PASS-OUT

During the past few years, the Klement Gottwald works, Brno (Erste Brünner Maschinenfabrik A.G.) have produced a number of single-cylinder turbines of the impulse type for medium pressures and temperatures, operating at 6000, 7500, or 9000 rpm and driving *via* gearing electric generators rated at 2000 kW. Such turbines were also made for the direct driving of turbo-compressors rated at approximately 530,000 to 1,060,000 cfh at a pressure 128 psia. Speeds were within the limits of 4600 to 6300 rpm, with outputs from 1850 to 3300 kW.

For otherwise equal conditions, the number of stages of both the high and low pressure parts depends on the extraction pressure. By careful design, it was possible to cater for a considerable range of the extraction pressure, i.e., about 28 to 170 psia. A typical turbine of this kind has a rating of 1500 kW at 3000 rpm, inlet steam conditions being 497 psia at 815° F, cooling water temperature 80·6° F, and extraction pressure 36 psia. Both regulating stages are Curtis wheels. The runner discs are integrally forged with the shaft. Both the admission valve and the extraction control valve are of the double seated type, and each has its own servomotor.

If such a turbine is used for driving a turbo-compressor, speed governing is as shown in Fig. 1. The orifice type of regulator (1) maintains constant pressure in the delivery pipe of the compressor and acts by means of pressure oil on the servomotor piston (2), which is positioned on a common rod with the transmitting piston (3). The latter controls the position of the restoring piston (4). The varying force due to pressure oil on the restoring piston changes the force exerted by the speeder gear spring (5) on the sleeve (6) of the speed governor. The change in position of this sleeve is used as an impulse for the " transmitter," which controls the regulating valves of the turbine. For different outputs of the turbo-compressor, the aggregate then has the speed corresponding to the required pressure.

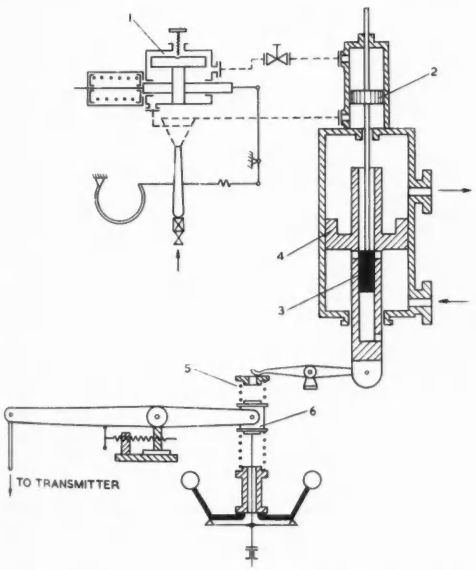


Fig. 1. **Speed governing of a turbine driving a turbo-compressor.**

For larger outputs (from 4000 to 7000 kW approximately), a number of single-cylinder turbines has been made, with direct drive for the generator and with impulse blading in the high-pressure part and reaction blading in the low-pressure part. Both regulating stages are of the Curtis type.

Two-cylinder condensing turbines, with single automatic extraction and high-temperature and high-pressure inlet conditions and with mixed type of blading, for ratings up to 24,000 kW, have also been built by the Gottwald works.

TWO-CYLINDER CONDENSING TURBINES WITH DOUBLE AUTOMATIC PASS-OUT

The Gottwald works have delivered a number of these turbines for the chemical industry. Technical data are as follows :—Output 24,400 kW ; inlet conditions 937 psia at 896° F ; first automatic extraction 298 psia, 59 tons/hr ; second automatic extraction 64 psia, 79 tons/hr ; cooling water temperature 80·6° F ; speed 3000 rpm. These turbines work in parallel into common extraction pipes and also into the main electric grid. The regulating stage of the high-pressure part is a Curtis wheel, the stages of the intermediate and low-pressure parts being single-row impulse wheels. With the exception of the low-pressure part, which has mixed blading, all blading is of the impulse type.

The layout of the governing system employed is shown in Fig. 2. The movement of the governor sleeve (1) is translated *via* the lever (2) to the sleeve (3) of the " transmitter " (4). The main oil-pump (33), driven by the turbine shaft, delivers pressure-oil, the gauge pressure p_0 of which is kept at a constant figure of 57 psig, and which is used for actuating the servomotors of the regulating valves. Part of the pressure-oil delivered by the pump flows through the valves *C* into the transmitter. Thus, oil delivered by the pump supplies both the power pipe line and the impulse-oil line. In the transmitter casing, from one side of the piston (5), there is the pressure of the impulse-oil p_x, counterbalanced from the other side of the piston by spring (6). In the upper part of piston (5) and in sleeve (3) there are oblong openings (7), through which oil constantly flows back to the tank. The size of these openings can be varied by changing the relative position of the sleeve and the piston. As the piston of the transmitter is spring-loaded, the pressure of the impulse-oil varies linearly with the piston position.

In the case of a stable state of operation, when the whole governing system remains inactive, the same quantity of oil flows through valve *C* and the openings of the transmitter, and is determined by the flow area of valve *C* and the pressure differential $p_0 - p_x$. There must be a definite relative position between the piston and the sleeve in order to have the same quantity of oil

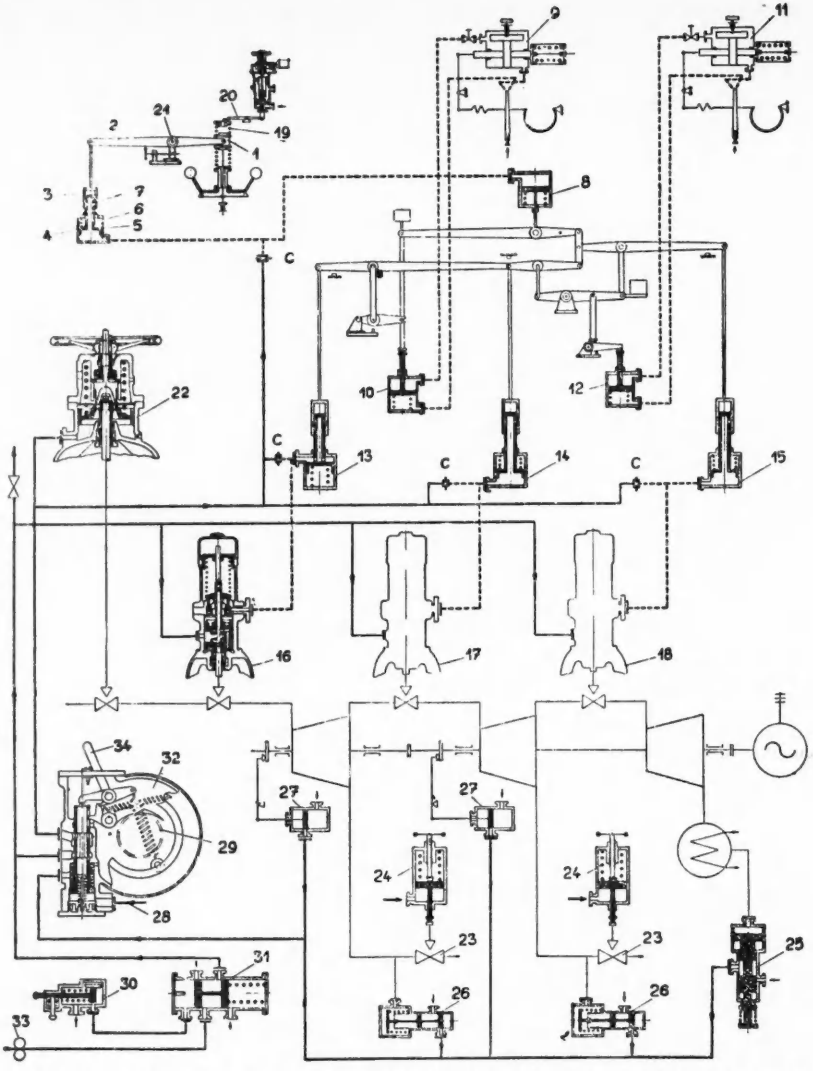


Fig. 2. Schematic layout of governing system of a condensing turbine with double automatic pass-out.

flowing at pressure p_x from the transmitter, through its openings, to atmosphere.

With increasing load, the speed decreases, the sleeve of the speed governor moves downwards, and the sleeve of the transmitter upwards. Consequently, the flow area of the openings is reduced, and the amount of oil passing through them is less than that arriving from the control valve *C*. The pressure p_x of the impulse-oil begins to increase, and the piston of the transmitter compresses the spring and moves upwards, In the new position of equilibrium, the pressure p_x' of the impulse-oil is again counter-balanced by the spring force. As the spring is now more compressed than it was previously, the pressure of the impulse-oil must also have increased, so that $p_x' > p_x$. The quantity of oil flow has become smaller, as the flow through valve *C* takes place at a smaller pressure differential. It can be proved that the flow area of the transmitter is also reduced, and hence the sleeve movement must be in the direction of the piston.

With decreasing turbine load, the whole process is reversed, and the pressure of the impulse-oil decreases. Oil from the transmitter (4) is led into the " receiver " (8) of the speed governor. The action of the speed governor and of the pressure regulators of both extraction points is communicated to all transmitters and receivers by an interconnected system of levers. The forces acting on the lever mechanism are very small, their magnitude being sufficient to move the sleeves of the transmitters. With increasing pressure of the impulse-oil, the piston of receiver (8) moves downwards and compresses the spring below the piston. The pressure regulator (9), maintaining a constant pressure for the first extraction (298 psia), acts on the piston of its receiver (10), so that, when the steam pressure in the extraction pipe decreases, the piston moves down-

wards ; with increasing steam pressure (less extraction), the piston of course moves upwards.

The pressure regulator (11), maintaining constant pressure in the second automatic extraction (64 psia), acts on the piston of its receiver (12). When the steam pressure in the extraction pipe decreases, the piston moves downwards ; when the pressure increases, the piston moves upwards.

The movements of the pistons of receivers (8), (10), and (12) are transmitted by levers to transmitters (13), (14), and (15), which control the opening and closing of control valves (16), (17), and (18), for the high-pressure, intermediate, and low-pressure parts respectively. Transmitters (13), (14), and (15) govern the pressure of the impulse-oil, as does transmitter (4).

In the operation of a condensing, double automatic extraction turbine, there are three independent variables, namely, the turbine output and the magnitudes of the two extraction quantities. The requirements to be satisfied by the governing system are inherent in the above described scheme ; in other words, the change of one variable does not influence the other two variables.

For bringing the turbine into phase and putting it under load (manually or by remote control), lever (20) changes the load on spring (19). Any persistent irregularity in speed governing can be eliminated by adjusting the position of fulcrum (21).

The turbine is started up by a manually operated and quick-closing valve (22), which makes rapid starting, or starting with insufficient oil pressure, impossible.

To safeguard against a back flow of steam from the extraction pipes to the turbine, each extraction point is provided with a combined non-return and shut-off valve (23).

Should the oil pressure fall below the required value, spring (24) closes the valve. This valve can also be closed manually.

The turbine is equipped with an additional number of safety devices, shown in Fig. 2, and intended for safeguarding vacuum, (25) ; extraction pressure at both extraction points, (26) ; axial movement of both rotors (27); and oil pressure, (28). In addition, there is an emergency governor for overspeed (29) ; a remote-controlled turbine shut-off (30), combined with fire-protection device (31) ; and a manual turbine shut-off (34).

In case of fire, the fire-protection device (31) connects the delivery pipe of the oil pump (33) with the drain pipe to the oil tank, so that the entire governing system receives oil for lubrication only, sufficient for the turbine run-out. The shutting-off impulses of all the above safety devices are transmitted hydraulically to a single common switch (32), which closes the stop valve (22), all nozzle control valves, and the non-return valves of both extraction points.

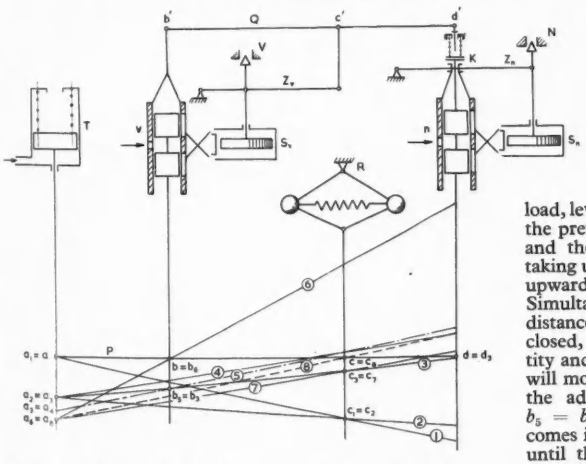


Fig. 3. Functioning of governing system for pass-out turbines.

GOVERNING SYSTEM FOR PASS-OUT TURBINES

To keep within the limit of permissible stresses in rotary parts, a steam turbine must shut off automatically when speed increases by 10 per cent. To prevent loss of time in restarting, standards are laid down to ensure that, even with a sudden drop in full load, the speed will not rise sufficiently to actuate the emergency governor. Consequently, under these conditions, not even a transient speed increase of 10 per cent is permissible.

Following a sudden decrease of load in the case of an automatic extraction turbine, extraction steam consumption is maintained and the pressure regulator of the extraction steam tends to keep the admission valve open ; on the other hand, the speed governor is called upon to close it as quickly as possible. Thus, the action of the speed governor is delayed, and shutting down of the turbine by means of the emergency governor would be inevitable.

To avoid this possibility, it is necessary, at the moment of closure of the extraction control valves, to prevent the pressure regulator from having any influence whatever on the admission valves, thus enabling a quick response of the latter to the speed governor. A governing system satisfying these requirements is shown schematically in Fig. 3. Here, R denotes the speed governor, T the pressure regulator, v and n the pilot valves of the admission valves V and extraction control valves N respectively; S_v and S_n are the corresponding servomotors, Z_n and Z_v the levers connected to the respective valve spindles. For the restoring movements of the pilot valves v and n, sliding-type sleeves are used. Q is the follow-up lever for the admission valves. Valves V and N close when the pistons of v, S_v, n, and S_n move upwards.

The horizontal position of lever P (points a, b, c, and d) corresponds to the no-load and zero-extraction condition of the turbine, i.e., with valves almost closed. The other operational positions of lever P are designated by numerals from 1 to 8. In the following description a notation is used in which, for example, point a of the no-load condition takes up a position a_1, a_2, a_3, etc., corresponding to the position lines (1), (2), (3), etc., respectively.

On increasing the load from the no-load condition, lever P moves into position (1), and after opening the extraction line, into position (2). Hence, distances cc_2 and aa_2 are the regulator travels proportional to the regulated quantities, and bb_2 and dd_2 the piston travels, to which the valve openings are proportional. If now, for constant extraction ($a_2 = a_3$) the load drops, position (3) is reached and the extraction control valves close, i.e., $d_3 = d$. Thus, the admission valves remain open, corresponding to bb_3. With further decrease in load, lever P shifts to position (4), which is determined by the previous position of the pressure regulator $a_3 = a_4$, and the new position of the speed governor c_4. In taking up position (4), lever P moves the piston of valve v upwards by a distance b_3b_4, causing valve V to close. Simultaneously, the piston of valve n travels upwards a distance d_3d_4 ; however, since valve N is already closed, it will remain closed. Both the extraction quantity and pressure decrease, and the pressure regulator T will move point a_4 into the position a_5, so arranged that the admission valve takes up its previous position $b_5 = b_3$. At this stage, however, the speed governor comes into play again, and the whole process is repeated until the pressure regulator reaches the end position determined by its design.

For complete unloading, the speed governor must come up as far as c_6, in order fully to close the admission valves, $b_8 = b$. As the speed governor travel cc_1 corresponds to full load (5 per cent speed variation), the travel c_1c_6 with complete unloading and extraction operation must be considerably larger, thus requiring a proportionally greater change of speed. This shortcoming is eliminated by stop K, one end of which influences the piston n, while the other acts upon the joint d' of the restoring lever Q. Stop K is pressed down by a spring, so adjusted that, as long as the piston moves downwards from the position corresponding to valves N closed, the upper part with point d' is in its lower position. As soon as piston n in its upward motion exceeds the point at which valves N are closed, stop K carries point d' upwards, so that d' describes the same movement as point d of lever P. The follow-up of the admission valve is jointed to lever Q at point c', so positioned that

$$\frac{b'\,c'}{c'\,d'} = \frac{b\,c}{c\,d} \qquad .. \quad .. \quad (1)$$

To clarify the foregoing description of the functioning of this system, consider the instant at which lever P just reaches position (3), and assume the extraction quantity to rise to its maximum value. The pressure regulator causes a movement to point a_7, while the speed governor remains at its position $c_7 = c_3$, so that lever P takes up position (7). Piston v moves downwards by a distance $b_3\,b_7$, and piston n upwards by $d_1\,d_7$. From the point d onwards, stop K also moves point d' when valve n moves upwards to reach position (7) of lever P; thus, the movement of d' is $d'\,d_7' = d_1\,d_7$. Therefore, lever Q pivots about point c', causing point b' to move downwards, and in turn to move the sleeve of valve v downwards by a distance.

$$b'\,b_7' = d'\,d_7'\,\frac{b'\,c'}{c'\,d'} \qquad .. \quad .. \quad (2)$$

From eq. (1), and because $d'\,d_7' = d_3\,d_7$,

$$b'\,b_7' = d_3\,d_7\,\frac{b\,c}{c\,d}$$

From the similar triangles given by positions (3) and (7) of lever P, the right-hand side of the above equation is

$$d_3\,d_7\,\frac{b\,c}{c\,d} = b_3\,b_7,$$

so that

$$b'\,b_7' = b_3\,b_7 \qquad .. \quad .. \quad .. \quad (3)$$

Thus, the sleeve has moved downwards by the same distance as the piston, and there is no relative movement between them. The servomotor S_v and the valves V remain at rest. In this manner it is possible to exclude the influence of the pressure regulator from the instant of closure of the extraction control valves.

If now, complete unloading takes place, lever P takes up its final position (8), and it will not be necessary for the speed governor to cause an upward movement beyond point c, in order to reach a greater change of speed than that corresponding to the condensing operation. What actually happens is an upward movement of piston v by a distance $b_7\,b_8$, whereas its sleeve will finally move downwards from its original position by

$$b'\,b_8' = d'\,d_8'\,\frac{b'\,c'}{c'\,d'} = d\,d_8\,\frac{b\,c}{c\,d} = b\,b_8 \qquad .. \quad (4)$$

Of the total travel $b_7\,b$ required to close the admission control valves, only a fraction $b_7\,b_8$ is due to the movement of the piston, while the remainder due to the sleeve movement $b_8\,b$.

It may be seen from the foregoing that, by using this governing scheme, no difficulties will be experienced by a sudden removal of grid load, as the main function of this system is based on a correct interpretation of the principles of true speed governing, without the emergency governor causing complete shut-off.

U. S. A.

Grinding Carbide Tools with Electrolytic Assistance

By N. W. THIBAULT and B. H. ANDERSON. (From *Metal Progress*, Vol. 64, No. 2, August, 1953, pp. 161-164, 166, 2 illustrations.)

DIAMOND-WHEEL grinding of cemented carbides, assisted by simultaneous electrolysis (electrochemical erosion or decomposition) of the cemented carbide, would appear to be a promising method for sharpening single-point tools.

Preliminary experiments were performed in 1952 on a tool and cutter grinder equipped with a specially constructed constant-pressure device to simulate off-hand sharpening of single-point tools. The first tests indicated that metal-bonded diamond wheels, supplemented by electrolytic action, using a proprietary rust inhibitor at a current density of about 250 A/sq in. were able to cut at a commercially acceptable rate. Only a small fraction of the amount of diamond was consumed as for the same rate of cut in conventional grinding using a vitrified-bonded diamond wheel. On the other hand, there was evidence of some attack on adjacent edges of the carbide by electrochemical erosion.

At that time, it was felt that this newer method should not be recommended for the commercial sharpening of single-point carbide tools until certain additional information had been obtained, including, (*a*) data on tool performance to ascertain whether the tools were adversely affected by the tendency for adjacent edges to be slightly eroded by electrolysis, (*b*) field experience to confirm laboratory conclusions as to rate of cut and diamond consumption, and (*c*) a thorough investigation of possible toxicity. Recent work has been directed towards an answer to these questions.

Since the laboratory set-up used for the preliminary experiments simulated an off-hand operation but was not suitable for grinding actual single-point tools, a Norton No. 2 "Bura-Way" tool grinder, which employs diamond wheels, was converted for electrolytic assistance. This machine is a precision tool grinder, which uses a tilting table, a universal tool-holder with protractor, or a specially constructed template, to duplicate exact tool form. In converting it for electrolytic assistance, the cartridge-type wheel spindle was insulated from the spindle housing by non-conducting sleeves. Direct current was supplied by copper oxide rectifiers, the secondaries of which were connected in series to supply 0 to 24 V, the maximum current rating being 230 A. External resistances could be varied in nine steps from 0 to 2·61 ohms. Current

was supplied to the insulated spindle by carbon brushes at the rear of the machine. In normal operation, the diamond wheel was negative and the carbide tool positive; means were provided for reversing polarity, should electrochemical dressing of the diamond wheel be required.

Field Experiments

After carrying out eight preliminary comparative tests, to obtain information on tool performance, arrangements were made with a large automotive concern in Detroit to continue the experimental programme. A large number of similar tools was available for regrinding, and high production operations would provide a better opportunity for evaluating tool performance.

Preliminary results are now available on two large carbide form tools of somewhat similar shape. Rough grinding was done with vitrified-bonded silicon carbide wheels, and finish grinding with the "Bura-Way" machine on side and end relief faces only; the top face of the tool was not ground.

Metal-bonded wheels were used with electrolytic assistance, vitrified-bonded for conventional grinding. The electrolyte was a proprietary brand of rust inhibitor, diluted with tap water and introduced to the centre of the wheel at a rate of 3 to 4 U.S. gpm. The average carbide removal at the top front of the tool by diamond grinding was 0·016 to 0·020 in.

For testing, the tools were used for rough turning of nickel steel on an automatic lathe; total depth of cut was about $\frac{1}{8}$ in. Criteria for judging tool life were ability to hold shape, and maintenance of satisfactory surface finish of the part. The tests are summarised in Table I.

Table I. Results of Tests in Automotive Plant

Test Data	Method of Grinding Tool		
	Conventional (Bura-Way)*	Electrolytic Assistance†	Off-Hand Grinders
	Grinding Data		
Number of tools ground	36	82	
Linear wheel wear per tool	0·00017 in.	0·00004 in.	
Finish grinding time per tool	4 to 5 min.	4 to 5 min.	
Tool finish, micro-in. r.m.s.			
Flat surfaces	5 to 9	4 to 6	
Profiles	14 to 16	10 to 14	
	Tool Performance Data		
Number of tools tested	26	33	41
Pieces per regrind, range	60 to 170	11 to 279	40 to 235
Arithmetic mean	112	134	124

*Vitrified-bonded diamond wheel
†Metal-bonded diamond wheel

From these data, it is concluded that, compared with conventional diamond-wheel grinding, the use of electrolytic assistance resulted in one-quarter the diamond consumption, and approximately the same rate of cut. Considering the relatively small number of tools tested and the variation in performance from tool to tool, it is believed that there is no significant difference in average performance of tools ground in the three different ways. Slight evidence of edge erosion was found when the tools ground with electrolytic assistance were examined under a magnification of × 75.

During the four months that the machine has been employed for electrolytic assistance, the electrolyte has not corroded any part of the machine or carbide tool shanks, nor has there been any evidence of electrochemical attack on the worktable or any other part of the machine.

To obtain comparative data from an off-hand operation, tests were conducted with the co-operation of a large carbide tool manufacturer, who had converted an off-hand carbide grinder for electrolytic assistance. In this test, 100 small tools of the same size and grade of carbide were finish-ground with a metal-bonded diamond wheel, electrolytically assisted. Current density varied considerably, but averaged about 250 A/sq in.; the same electrolyte as that mentioned above was used. Results were compared with data obtained previously on 200 tools of the same size and type of carbide conventionally ground with a vitrified-bonded diamond wheel, and showed that the electrolytically assisted operation required only slightly more than one-quarter the amount of diamond, but cut approximately 8 per cent more slowly, compared with the vitrified-bonded wheel used conventionally.

Tools ground with electrolytic assistance showed the variable, dull matte finish associated with this method of grinding, and there was some evidence of edge erosion at high magnification. Both of these factors, the manufacturer felt, would result in customer acceptance problems at the present time, although it is reasonable to conclude that these tools ground off-hand with electrolytic assistance probably would have performed satisfactorily.

Since the electrolytically assisted method depends in part on electro-chemical decomposition of the carbide, it would be logical to expect that toxic gases might be generated by decomposition of the electrolyte. The toxic gases most likely to be present would be ozone and nitrogen peroxide (a mixture of NO_2 and N_2O_4). Gas analyses were therefore made at the operator's breathing level, using the laboratory set-up; current density was 250 A/sq in. A general exhaust was placed above the machine about a foot away from the grinding contact.

The analyses showed 11 to 16 parts per million of nitrogen peroxide, as against the permissible limit of 25 parts per million for an 8-hr exposure per day. Ozone was 1·5, compared with a permissible limit of 1. A suitable exhaust, closer to the working area, would undoubtedly reduce the ozone value to where it would be in the permissible range.

The ultimate goal of electrolytic operation is to eliminate the use of diamond entirely in the sharpening of single-point carbide tools. Most of the recent laboratory work on this project has been concentrated on diamond-free electrolytic operations. Although details cannot be revealed at this time, two different methods of operation have been developed, both of which show a certain degree of promise. Maintenance of a satisfactory rate of cut, and reduction of edge erosion to satisfactorily low levels have been two of the many difficulties encountered. They require much more investigation before the practicability of the process can be definitely established.

Conclusions

Electrolytically assisted diamond-wheel grinding of single-point carbide tools appears to be even more promising than it was in the latter part of 1952, when the first report was published. Laboratory results have been confirmed by controlled comparisons, in which actual carbide tools have been ground. In every test, a considerable amount of diamond bort was saved (about 75 per cent), and rates of cut were equal to or slightly less than those obtained with vitrified-bonded diamond wheels used conventionally. Tool performance was as satisfactory as that of tools ground conventionally. A toxic condition may arise from gas generation by electrolysis, but this apparently can be overcome by a suitable exhaust placed near the grinding contact.

In spite of these promising results, it is felt that caution should be exercised in replacing conventional diamond-wheel grinding of single-point carbide tools by any of the newer methods at the present time.

Nevertheless, it seems desirable to continue the development of alternate machining methods employing less diamond (or none at all) as actively as possible, and research and development programmes are being pursued in several directions in this connection.

Displacement Pump of Unconventional Design

By B. I. APOLTCHIN. (From *Vestnik Mashinostroyenya*, June, 1953, pp. 43-44, 4 illustrations).

THE pump described in this article is different from conventional pumps operating on the displacement principle. Its action, shown in Fig. 1, is as follows :— On the inside surface of cylinder (1), an elastic hose (2) is arranged as a hollow ring. A roller (4), with its axis mounted on a crank rotating about a shaft (3), compresses the hose at the point of contact, thereby dividing the hose into two parts. During the rotation of the shaft in the direction of the arrow, the roller will traverse the inner surface of the cylinder, thereby displacing liquid (or air) from the part of the hose in front of it and sucking fluid into the part of the hose behind it. When the roller is in the upper position, it simultaneously compresses both ends of the hose, thereby permanently sealing off from each other the pressure and the suction chambers.

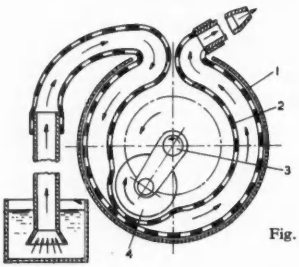


Fig. 1

From this description it is clear that the basic feature of the pump is an elastic chamber whose shape determines the design of the pump. Such a chamber for a small pump is shown in Fig. 2. It consists of a narrow rubber bag, bent into a shallow, hollow ring, one end of which terminates in the delivery tube. A suction inlet is bonded near the sealed end and connects the internal space of the chamber with the fluid to be pumped. A number of bolts, with disc-shaped heads, is bonded in opposite pairs to the side walls of the bag and is evenly distributed around the circumference. The purpose of these bolts is to enforce the expansion of the chamber during the suction period, as its natural resilience would be insufficient to produce the action shown diagrammatically in Fig. 1. The rubber chamber is reinforced by several layers of canvas and cord and in its detail design strongly resembles an automobile tyre.

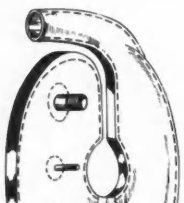


Fig. 2

Fig. 3

To be able to communicate a motion capable of producing fluid displacement, the hose must be subjected to a certain sequence of deformations. In this design an obtuse-angled cone (Fig. 3) is used which rolls over a flat disc, so that the generating line of the cone touches the disc radially along its whole length. The line of contact continuously rotates around the disc. The opposite generating line of the cone forms an acute angle with the disc. The rubber chamber is fastened on one side to the surface of the disc and on the other to the surface of the cone (Fig. 4). The rolling motion is brought about by a swashplate mechanism, consisting of an inclined eccentric, on which the cone, mounted on a ball bearing, is located. This mechanism does not cause the cone to rotate about its own axis but only to roll along the surface of the working chamber. Thus, sliding friction is totally absent in the operation of the pump.

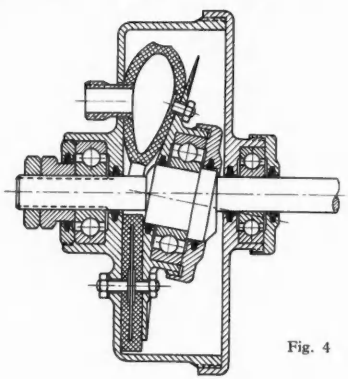


Fig. 4

The design of this pump is distinguished by the total absence of valves, seals, piston rings, and similar components. Not only are seals completely eliminated but the pump is hermetically sealed—a great advantage in many applications.

For the purpose of carrying out industrial tests, several prototypes of this pump (up to 100 of each size) were made, with deliveries between approximately ¼ and 13 gpm, delivery heads of about 130 to 165 ft of water, and rotational speeds between 20 (manual drive) and 1,000 and more rpm.

On the basis of the tests carried out, the following conclusions were reached :—

(1) The pump is extremely simple and easy to produce. The manufacture of the rubber chamber is not complicated and can be effected even in a small tyre-repair shop.

(2) Owing to its completely hermetic sealing, this pump has high vacuum characteristics, and approaches the maximum theoretical suction lift attainable under given atmospheric conditions. It does not lose this characteristic or allow it to deteriorate during its working life, even with heavy wear in the ball bearings.

(3) The pump is not sensitive even to very dirty liquids, e.g., water with a large content of sand.

(4) It can operate within a very wide range of rotational speeds (from a few rpm up to 1,000 and more) without changing its characteristics. For this reason, it can be used successfully in installations with either manual or mechanical drives.

(5) Because of the simplicity of its design and the absence of valves, seals, etc., it requires no maintenance and can be operated without supervision. Replacements are confined to worn-out rubber chambers and ball bearings. The service life of a rubber chamber depends on many factors, but in spite of inadequate manufacturing

(*Concluded on page* 438)

A Survey of Rapid Fatigue Test Methods

By G. VIDAL. (From *La Recherche Aéronautique*, No. 34, July-August, 1953, pp. 49-54, 11 illustrations.)

A survey of existing so-called "rapid" or abbreviated methods for the determination of the fatigue limit leads to the conclusion that no such method gives a reliable indication of the fatigue limit. However, with caution, some of these methods may be used as approximations, thereby reducing the number of tests required by the strict method.

THE fatigue limit is usually defined as the maximum pure alternating load a metal or alloy can carry indefinitely without fracture. As, in practice, the fatigue limit is accepted as the maximum load which does not fracture a certain type of test specimen in less than 10 million or 100 million loading cycles, its determination obviously requires a number of lengthy tests up to fracture, and it is understandable that many attempts have been made to establish a more rapid method of testing. However, whereas the true fatigue limit is entirely dependent on the final fracture and is thus not directly connected with any irreversible mechanical or physical change which may become apparent before fracture, the limiting loads of rapid methods indicate alternating stress levels at which such an irreversible change, e.g., in magnetic or thermal properties, will just commence. Consequently, these limits are only vaguely connected with the classical fatigue limit and moreover share with the elastic limit—the starting point of irreversible extensions—the disadvantage that their exact determination depends to an unknown extent on technique and on the accuracy of the measurements.

Another general criticism is that the small local disturbances initiating fatigue cannot directly influence, or be related to, the changes in overall properties measured in some rapid methods. It seems, therefore, that accurate abbreviated methods do not, and probably cannot, exist.

The most satisfactory method of speeding up tests would seem to be that of increasing the speed of the testing machine. Push-pull fatigue machines running at 15,000 cpm have been built, and in spite of their cost and complexity they should lead to considerable progress in fatigue research.

Where the fatigue limit is unknown in order of magnitude, e.g., in the testing of new materials or of special components and assemblies, a rapid method may be used to provide a first indication of suitable loads for the final strict fatigue testing, and to restrict in this way the number of tests and specimens required. For this purpose, the most suitable method which does not require any additional equipment at all, consists of very slowly increasing the load during the test until fracture occurs. Although the practical engineer can thus make little use of rapid methods, the metallurgist would be interested in the new properties divulged by these tests, namely the initiation of complex physical changes at a certain level of applied alternating stress, even below the elastic limit of the material. Unfortunately, investigators have so neglected this aspect of their work that any scientific deductions must remain vague.

Some of the methods proposed for rapid testing are as follows :

(1) *Measurement of Temperature*[1, 2, 3, 4]*:* The applied alternating stress is progressively increased until a rise in temperature of the specimen can be observed by means of a thermocouple. The limiting maximum stress thus found does not correspond to the classical Wöhler limit : The two steels in Fig. 1[5] have the same Wöhler limit (23 tsi) but have different heating levels (16·5 and 23 tsi respectively). The limiting load here seems rather to vary in the same sense as the elastic limit ; it would thus, as expected, be bound up with the shape of the stress-strain diagram, since this shape determines the heat evolved by mechanical hysteresis. The question remains unanswered how far the level found by this method really indicates a change in the hysteresis loop of each successive cycle and how far it represents a mere accumulation of heat due to rapid repetition of the initial, unchanged hysteresis loop. Investigators have so far used only repeated bending or torsion tests, where the stresses decrease towards the centre ; more heating, hence lower limiting stresses, can be expected in push-pull tests.

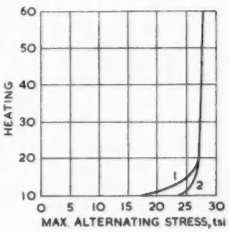


Fig. 1. **Heating of steel test piece under increasing alternating stresses.**
(1) Normalised ; (2) Normalised and tempered at 600° C.

(2) *Measurement of Deflection*[2, 3, 6, 7]*:* A cantilever specimen (Fig. 2) is rotated under a static load, progressively increased in small steps, and the deflection of

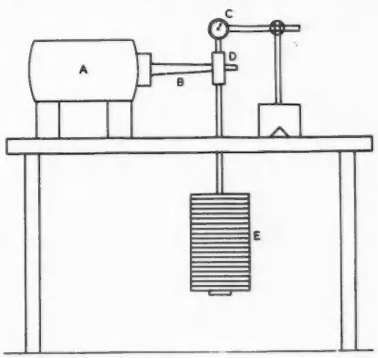


Fig. 2. **Measurement of deflection in rotating fatigue tests.** A = Drive motor ; B = test piece ; C = dial gauge ; D = ball bearing ; E = load.

the free end is measured. According to one method[5], the limiting load, said to represent the fatigue limit, is reached when the deflection no longer increases proportionally with the load, as shown in Fig. 3. In another method[8], each load is held constant for 12,000 revolutions and the deflection measured at the beginning and end of this period ; the limiting load is said to be reached when the deflection starts to increase during this period[4]. (Fig. 4). This increase in deflection naturally does not correspond to a permanent deformation, as the specimen still runs true when deflected ; it corresponds rather to a decrease in the rigidity of the specimen, partly due perhaps to working under plastic but reversible conditions just beyond the elastic limit and certainly due in some measure to the simple decrease of Young's modulus with increasing temperature of the specimen. It is not, however, stated whether the deflection decreases again when the machine is stopped.

The complexity of this phenomenon is clearly shown (see Fig. 5) by the fact that, as the number of cycles in-

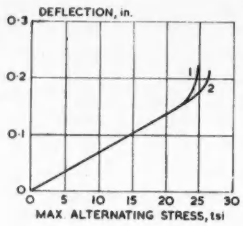


Fig. 3

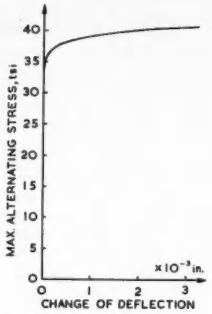


Fig. 4

Fig. 3. Deflection of steel test piece under increasing alternating stresses.

(1) Normalised; (2) Normalised and tempered at 600° C.

Fig. 4. Difference in deflection before and after 12,000 revolutions at constant load of different magnitudes.

Steel, oil-quenched and tempered at 600-650° C.

creases under constant load, the deflection first increases, then decreases again, and finally increases once more up to fracture[9]. Moreover, one author[1] states that the deflection limit is identical with the previous heating limit, whereas other authors[5, 6] find no such relationship. The criterion is thus not well defined scientifically; it certainly is not directly connected with the classical Wöhler fatigue limit, since materials of equal Wöhler limit can be shown[5] to have different deflection limits. A relationship with the static elastic limit seems more likely, but test data are insufficient for a closer analysis. A third, inverse, deflection criterion for the fatigue limit has also been proposed[7]. A statically pre-stressed torsional specimen is oscillated through a given angle, which is increased at intervals, and the smallest angle leading to a drop in the static stress is taken to represent the fatigue limit. The preceding criticism also applies to this method.

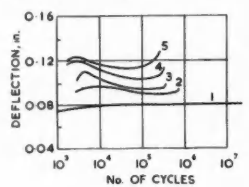


Fig. 5

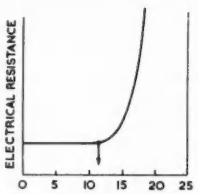


Fig. 6

Fig. 5. Change of deflection with the number of cycles under alternating stress of constant amplitude.

Commercially pure iron :—(1) = 11·7 tsi; (2) = 13·4 tsi; (3) = 14·2 tsi; (4) = 15·0 tsi; (5) = 15·2 tsi.

Fig. 6. Change of electric resistance as a function of applied alternating stress (0·88 per cent carbon steel).

(3) *Measurement of Electric Resistance*[10]. The load on a rotating bending fatigue specimen is increased every 3000 cycles and the electric resistance is measured. The minimum load producing an increase in electric resistance (Fig. 6) is said to be the fatigue limit. The heating of the specimen obviously again plays an important role. No comparative tests of the Wöhler fatigue limit are given, but the following results on plain carbon steels show that the limit here is very much below the true Wöhler fatigue limit :

APPROXIMATE FATIGUE LIMITS OF PLAIN CARBON STEEL.

Carbon content, per cent	0·11	0·22	0·41
Resistance limit[10], tsi	5·0	6·1	7·1
Wöhler limit[9], tsi	14·6	14·6	19·0

This method, therefore, does not give even an approximate value of the classical fatigue limit, though the electrical phenomenon itself is detected with great sensitivity. In steels with many inclusions, the electrical resistance mounts suddenly at a certain value of the alternating stress, probably because, independently of the temperature, the micro-cracks starting from the inclusions reduce the current-carrying cross-section.

(4) *The Minimum of the Coefficient of Expansion*[11]. After various test specimens have been subjected to different alternating stresses for 100,000 cycles each, their mean thermal coefficient of expansion between 25 and 45° C is determined with great accuracy. The resulting curve (Fig. 7) shows pronounced variations and

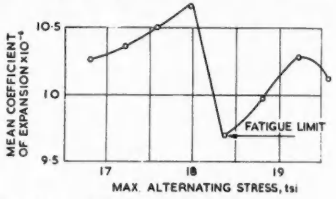


Fig. 7. Variation of the mean coefficient of expansion, between 25 and 45° C, after previous stressing under alternating loads.

the alternating stress leading to the minimum value of thermal expansion is taken to be the fatigue limit. The range of alloys so far tested is too limited for any conclusions of general validity. The authors state that theirs is the " true limit of fatigue " and that the Wöhler limit can finally be deduced from it by a small number of tests. It follows that this criterion also does not supply the Wöhler fatigue limit.

(5) *The Maximum of the Inverse Magnetostrictive Effect*[12]. If, during a static tension test of a magnetic alloy, the specimen is surrounded by an electromagnetic coil and the variation of its magnetic permeability is measured in an inductive field at 1000 cps, the following changes will be observed (Fig. 8): The permeability first rises (line *OA*), then remains stable (*AM*). The point *M* corresponds to the elastic limit of the specimen and the permeability changes are reversible up to point *M*; once the point *M* has been exceeded, the permeability drops irreversibly. A few cycles of repeated tension from zero to a steadily increased maximum value are now taken and the permeability changes are measured for each cycle. As the peak tension exceeds the value of the tension for point *M*, the initial slope *OA* in Fig. 8 steepens and reaches a maximum gradient (Fig. 9) for a value σ_γ of the peak tension; σ_γ is stated to be exactly equal to the classical Wöhler fatigue limit. However, this optimistic conclusion remains to be confirmed for various types of steel and various values of the inductive field.

(6) *The Maximum of the Static Fracturing Stress*[13]. A number of specimens is subjected to constant, though

Fig. 8. Variation of the magnetic permeability as a function of the applied static stress.

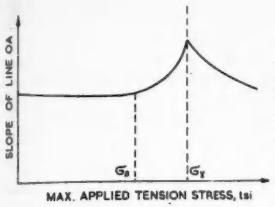


Fig. 9. **Change of slope of line OA (Fig. 8) as a function of the applied peak stresses during a few repeated tension tests (zero to maximum) of increasing amplitude.**

different, values of alternating stress for $1{\cdot}4 \times 10^6$ cycles and the static fracturing stress of each specimen is then determined. A curve of alternating pre-stress against static fracturing stress shows a maximum of the static stress for a certain value of the pre-stress and this value is stated to be equal to the fatigue limit of the alloy tested, at least within 10 per cent. Although a wide range of metals has been tested (black, bright, and notched steel, brass, monel metal, and duralumin), no sharply differentiated systematic investigations have been published. The investigators explain that below the Wöhler limit the strain-hardening effect of the alternating loading tends to increase the final static strength, whereas, above this limit, structural damage due to cracks will tend to diminish it. The changes in the static strength, however, are small and hence the fatigue limit must be found as the tangential point on a small curvature—a disadvantage of this method. A strict scientific analysis of the method is difficult because of the exclusively technological criteria used.

(7) *Testing with Steadily Increased Loading*[14]. Several fatigue tests are conducted with loads uniformly increased at a constant rate, different for each test. The alternating stress at fracture in each of these tests is plotted against the square root of the rate of increase and linear extrapolation to zero rate is said to give the fatigue limit. This limit, however, certainly does not coincide with the Wöhler limit, as a test at increasing loads first understresses the specimen, then leads into the region of overstressing, thus including two factors which are known to affect the fatigue limit in a complex manner. On the other hand, a very slow increase in the load will lead to at least an approximate value of the Wöhler limit, so that subsequent rigorous tests can be restricted to a minimum. Moreover, this method of a slow increase resembles the classical method in that the final fracture is accepted as the only true fatigue criterion. Another advantage is that this method needs no equipment additional to the classical fatigue test apparatus.

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The Design of Electroformed Parts

By W. H. METZGER, JR. and V. A. LAMB. (From *Machine Design*, Vol. 25, No. 9, September, 1953, pp. 124-131, 9 illustrations.)

Although electroforming, or the production of parts by electrodeposition of a metal on a removable mould or matrix, is a process over a hundred years old, its uses prior to fairly recent years were, with the exception of a few special applications, such as the production of electrotypes and gramophone record dies, few and far between. In the past ten to fifteen years, however, electroforming has been increasingly applied to a wide variety of articles, until to-day it occupies a significant position with other methods of metal fabrication.

APPLICATIONS OF ELECTROFORMING

Design engineers can be guided by certain general principles in deciding whether electroforming is a feasible method for making a given part. Some of the more important criteria are as follows :—

Form: Many shapes, both simple and complex, can be electroformed. If parts are of such form that they can be readily made by standard methods, such as machining, casting, stamping, or drawing, electroforming cannot usually compete on a cost basis. However, even in the case of simple shapes, electroforming is sometimes the best fabrication method. For example, a thin-walled part such as a pen-cap has been successfully and economically manufactured by electroforming. The thin wall permits a high rate of production and makes possible a good as-plated finish. An additional advantage in this application is that a machining operation, required for mechanically formed caps, is unnecessary with the electroformed caps.

On the other hand, electroforming is not restricted to simple shapes. On the contrary, one of its important advantages is that shapes which are too complicated to produce economically by standard methods can be reproduced at a practical cost by electroforming. Another class of component is that containing "grown-in" components. For example, pins or plates intended to project into the inside of a wave-guide can be incorporated in the mandrel. The electroformed metal adheres to or firmly embeds the projecting portion of the insert and it becomes an integral part of the completed piece. Similarly, contact wires can be "grown-in" to an electroformed commutator or slip-ring element.

Size: Parts of almost any size can be made by electroforming, ranging from tiny silver slip-ring assemblies to searchlight reflectors five feet in diameter. Even larger parts have been electroformed.

Deposit Thickness: Parts such as hollow spheres and tubes have been made with wall thicknesses of only a few ten-thousandths of an inch. These parts could have been made by no other method. Thick deposits can also be readily made. Moulds for plastics, and metal forming dies are examples of thick-walled electroformed parts. The practical upper limit of thickness may be considered to be in the range of 0·25 to 0·5 in.

Accuracy of Reproduction: One of the important features of electroformed parts is the high accuracy of dimensions and finish obtainable. Scratches of the

order of one-millionth of an inch in width or depth are accurately reproduced. Ability to reproduce a high surface finish is of special value in producing parts such as mould cavities for plastics, and waveguides for microwave transmission. The desired finish and tolerances can be readily applied to the outside surface of the matrix, and are automatically reproduced on the inside of the waveguide, whereas to achieve the same finish and accuracy on the inside by machining methods would be nearly impossible.

Production Runs: The number of pieces of a given design to be made may be an important factor in deciding between electroforming and some other method of fabrication. For example, suppose that an experimental assembly contains a cup-shaped part and, to determine the optimum dimensions of this part, trial of several sizes and shapes is necessary. The experimental parts can be readily made at moderate cost by electroforming. However, once the design is fixed, a large number of this design can be made at a lower cost by drawing. Much time and the relatively high cost of several drawing dies are thereby saved.

Types of Mandrels

The mould or matrix upon which the electroformed part is made is usually a negative of the desired product. An under-dimensioned positive mould can also be used, but the outside surface of the product will not be an accurate reproduction of the part being made, unless it is thin-walled.

Matrices can be made by any standard method of fabrication, such as casting or machining. Electroforming is also a good method for making matrices. A number of highly accurate negative matrices may be made from a single machined positive.

Matrices may be classed as permanent, soluble, or fusible, and their basic characteristics are :

Permanent Types: A permanent, or re-usable, matrix is employed when the shape is such that it can be withdrawn without damage to itself or to the electroformed part. A metal is generally used for this type of matrix, although wood, glass, or plastic can be used. A wide choice of metals is available. Each matrix material has certain advantages and limitations. The more common materials are as follows :

Plain Steel: Plain steel can be machined accurately, it is readily available, and its cost is low. It cannot be used without a suitable protective coating in acid copper or hot iron-chloride plating solutions owing to chemical attack by these solutions. It can be used without a protective coating in a nickel solution or in any cyanide-type plating bath. Plain steel may be plated with an adherent coating of any corrosion-resistant metal, to permit its use in these corrosive baths. For example, nickel, chromium, or silver may be employed. These coatings also facilitate formation of separating films on the matrix. The high hardness of a matrix coating of chromium prevents damage by accidental scratching or denting. If the matrix is to be used in a corrosive bath such as copper, a rather heavy coating of the protective metal should be considered, e.g., a minimum thickness of 0·002 in.

Stainless Steel and Inconel: These alloys have good corrosion resistance and are inert to most plating solutions. The natural oxide film, which is responsible for the passivity of these alloys, prevents adhesion of most deposits. However, it is usually desirable to ensure passivity by special treatment. These alloys are not very hard and unless matrices made from them are very carefully handled, a high surface finish will be damaged.

Invar and Kovar: The important characteristic of these alloys is their unusually low coefficient of expansion. They also have a natural passivity similar to that of stainless steel. High cost and poor machinability are disadvantages. They are most useful for long, untapered matrices. In this situation, as a result of their low coefficient of expansion, heating of the electroformed part on the matrix may result in sufficient differential expansion to facilitate withdrawal.

Brass: Brass has good machinability and is low in cost compared with the special alloys. If it is plated with a suitable coating, such as nickel, chromium, or silver, it can be used in any plating solution.

Glass and Quartz: These materials can be ground to extremely small tolerances and to a very high surface finish. High cost of machining and fragility are disadvantages. Surface strains may cause failure by crazing. Glass matrices must be coated with a conducting film. Silver, applied by either chemical reduction or by evaporation, is usually employed.

Wood, Plaster, Plastics: High tolerances cannot be held with these materials, especially wood and plaster. Plaster matrices are likely to be damaged when removed and are therefore not strictly re-usable, but are considered here because they are neither soluble nor fusible. The surface pores of both wood and plaster must be sealed with varnish or wax, and require application of an electrically conducting coating. Copper or silver powder in a lacquer vehicle is generally used. Plastic matrices can be made with a high finish and fairly small tolerances ($\pm$ 0·001 in.), which would be lost if a conducting lacquer were used to make the surface conductive. Therefore, a thin silver film is usually applied, either by chemical reduction or by evaporation.

A special type of plastic matrix is one which remains a part of the finished article. Two examples of articles in this category are electroformed slip-rings and commutators, and electroformed circuits. Slip-rings and commutators are made by building up thick deposits of silver in grooves moulded or machined into the plastic base. Electroformed circuits may be made by depositing silver or copper on a pattern printed with a conducting paint, in order to increase the conductivity of the circuit.

Soluble Types: A soluble matrix is useful in the following situations :—(1) When a higher finish and smaller tolerances than those obtainable with a fusible matrix are desired, but where a permanent matrix cannot be withdrawn ; (2) in cases where creep would distort fusible metal or wax matrices ; and (3) in cases where a thin-walled electroformed part has insufficient strength to permit withdrawal of the matrix.

Soluble matrices are most commonly made of aluminium, which can be dissolved by a caustic solution without attacking electroformed copper, silver, nickel or iron.

Polystyrene plastic matrices may be made cheaply with fairly close tolerances by injection moulding and can be removed from the electroformed part with a suitable organic solvent.

Steel or zinc matrices can be removed by dissolving in hydrochloric acid. Steel, however, is not very practical as a soluble matrix because it dissolves very slowly.

Fusible Types: In cases where the shape will not permit withdrawal of the matrix, but where the accuracy of a soluble matrix is not needed, fusible matrices are used. Made from either low-melting alloys or waxes, matrices are formed by casting, although wax matrices may also be pressure-moulded. Casting may be effected in simple moulds of steel, plaster, or wood, or in high-production applications by die-casting. Hollow spherical floats are generally produced with a cast positive matrix and, as a typical example, electrotype moulds are made with moulded matrices.

Alloys of the lead-tin-bismuth type, with melting points of approximately 158°, 255°, and 281° F, are commonly used low-melting alloys. Many waxes are suitable as matrix materials, including paraffin, beeswax

and electrotyper's wax. Tolerances as low as ± 0·002 in. may be obtained with cast metals and waxes.

Separating and Conducting Films: Two subjects concerning matrices which are of importance in electroforming are methods for separating the finished part from the matrix, and methods for applying conducting films to non-metallic matrices. These subjects are not, however, of primary interest to the designer generally, with the exception of one separation method.

It is sometimes advantageous to obtain separation of the electroform from the permanent metal type of matrix by plating the matrix with a thin deposit of a low-melting metal, such as lead, tin, or cadmium, and then effecting removal by melting the separating film. This method is especially useful in the case of deep cavities, or long tubes with no taper. If the dimensional tolerances are small, the matrix must be made undersize to compensate for the thickness of the fusible plate, usually of the order of 0·001 in.

Design Factors

Most of the design limitations are the result of the inability of a plating bath to produce a deposit of uniform thickness on an irregularly shaped matrix. A deposit tends to be thicker on projecting areas and thinner in recesses than the average thickness. If a recess is sufficiently deep, the bottom of the recess may receive no deposit at all. The degree of thickness uniformity which a given type of bath will produce on an irregular surface is a function of a qualitatively defined property of the bath, known as throwing power.

Acid-type plating solutions, such as iron, nickel, and copper sulphate, have relatively poor throwing power, while cyanide baths, such as silver and copper, have relatively good throwing power. The electroformer can compensate to some degree for irregularities in form and low throwing power by the use of auxiliary conforming anodes, " thieves " (cathodic elements which rob current from areas such as edges and projections), and shields (non-conducting plates arranged to deflect the current from projections).

These expedients add to the cost of the electroformed part and if the need for them can be eliminated by designing for electroforming, a gain has been made. Functional requirements may dictate shapes and designs which present problems for the electroformer, but these problems will be lessened if the designer knows of the limited throwing power of plating solutions and if his goal is to minimise the problems arising therefrom. Observation of the following rules will aid in achieving this goal :—

(1) Recesses should be as wide and as shallow as possible.
(2) Sharp internal angles should be avoided, wherever possible. Internal angles should preferably be obtuse, with fillets at their apices.
(3) Projections preferably should have rounded contours, and outside angles should have radii at their apices.

These rules are illustrated diagrammatically in Fig. 1.

Quantitative data, permitting prediction of the deposit thickness on any part of a complicated shape, would be very useful in electroforming. Unfortunately, such data do not exist, but certain qualitative relations between deposit thickness and angles can be predicted. For example, in internal angles, the smaller the angle and the smaller the fillet radius, the less should be the thickness of the deposit in the apex relative to the thickness at a distance from the apex. On the outside of an angle, the reverse should apply.

It is theoretically impossible to deposit metal in the apex of any sharp angle. However, sharp internal angles do fill in with electrodeposits of sufficient thickness. Columnar crystals grow out from the sides of the angle to meet in a cleavage plane bisecting the angle. The strength of the metal in such a cleavage plane is

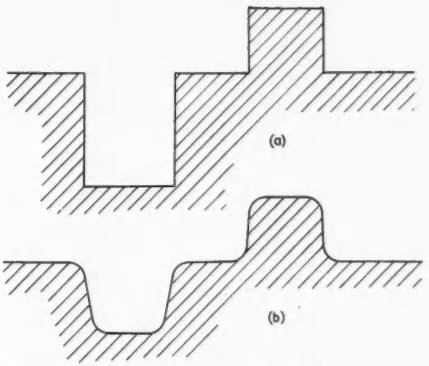


Fig. 1. **Cross-sections of hypothetical matrix contours**
(a) Undesirable design, with sharp corners.
(b) Desirable design, with rounded contours.

very low. This condition can best be avoided by use of a fillet at the apex of the angle.

Experience indicates that the following approximate rule applies :—A fillet whose radius is equal to or greater than the thickness of the electrodeposited metal will prevent the formation of a cleavage plane in the apex of an internal angle. Fig. 2 illustrates the geometric basis for this rule. It shows also that if the

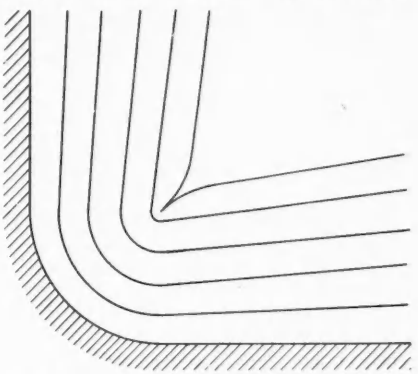


Fig. 2. **Cross-section of an electrodeposit in a filleted internal right-angle.**
The lines indicate the changing form of the deposit in the corner with increase in thickness, and show the initiation of a cleavage plane in the corner, when the deposit thickness exceeds the radius of the fillet.

deposit is thicker than the radius of the fillet, a cleavage plane will form in the portion of the deposit in excess of this thickness. Such a " combination " deposit in an angle will naturally be stronger than one with no sound deposit in the angle. If a part with a sharp internal right angle requires both strength and a sharp corner, a substantial thickness of metal can first be deposited in the corner, following which a fillet can be formed with solder, sprayed metal, low-melting alloy, or plastic. A sound deposit can then be built up over this fillet. The cross-section of such a corner is shown in Fig. 3.

Sharp outside angles do not present as difficult a problem as do sharp inside angles, and can be employed if needed. However, if not essential, replacement by rounded-off contours may result in lower costs, through elimination of thieving, intermediate machining, etc.

In addition to the above rules on angles and recesses, the following points should be considered by the designer :—

(1) Certain combinations of metals as parts of the same matrix may present difficulties. For example,

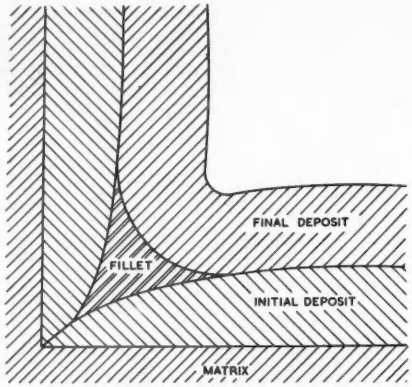


Fig. 3. **Cross-section of a deposit in a sharp internal right angle, showing a method of obtaining strength in the angle.** The fillet is formed with solder, low-melting alloy, sprayed metal, or plastic. Cleavage plane is absent in the final deposit.

plain steel inserts or joining pins are just as susceptible to attack by an acid copper solution as are other parts of the matrix. This is often overlooked by the designer or machinist who places such inserts in a matrix made mainly of an inert material, such as stainless steel.

Copper or brass inserts in an aluminium matrix cause difficulty in pre-plating processing. If such combinations are contemplated, the designer is advised to consult with the electroformer regarding their suitability.

(2) The design should include some sort of "handle" on the matrix. For example, a waveguide matrix requires extra unplated length to provide a reference point for machining the outside surface. A handle may also serve as a means for suspending the matrix in the plating bath and for making electrical contact.

(3) In the case of permanent matrices, provision should be made for applying a separating force, for example, by means of a screw or an arbor press.

(4) In the case of soluble matrices, provision for circulating the dissolving agent through the matrix will greatly increase the speed of dissolving. Thus, an aluminium matrix for a waveguide should be drilled with a hole extending its full length.

(5) As an approximate guide, it may be stated that average deposit thickness can be controlled to ±10 per cent. If the shape is simple, thickness variation from point-to-point may also be held within ±10 per cent but, if it is complex, the thickness may vary several-fold between thick and thin areas.

(6) The designer should consult with the electroformer at the earliest possible stage of the design.

Metal Selection

Twenty-two pure metals can be plated from aqueous solutions. For various reasons, such as undesirable physical properties, or inability to obtain satisfactory thick deposits with baths known at present, only four of these are commonly used for electroforming. These are copper, silver, nickel, and iron. One of the advantages of electroformed metals is that physical properties can be varied over a fairly wide range by simply changing the conditions of deposition, such as solution composition, current density, temperature, and addition agents. Physical properties can be further controlled by annealing, or, in the case of iron, by case-hardening. However, the latter treatments may lead to dimensional distortion. A shrinkage stress is present in most electrodeposited metals, and this may lead to subsequent dimensional changes. For example, it has been determined that stress causes a linear shrinkage of nickel electrotypes of about 0·1 per cent. Considerable work has been carried out to develop methods for reducing stress in nickel deposits.

There are practically no published data on the effect of stress on the dimensions and stability of electroformed parts. There is some evidence that thick deposits, when constrained from moving, as is the case when deposited on a rigid matrix, undergo self-relief of their stress during deposition.

In addition to its possible effect on dimensions, high stress in an electroformed part makes its removal from the matrix difficult, because the stress, being contractile, shrinks it against the matrix. This does not apply in those cases where the part is electroformed against a flat matrix or on the inside surface of a matrix.

If precautions are taken to obtain deposits with the lowest possible stress, dimensional changes resulting therefrom are probably negligible.

Iron electrodeposits from the commonly used baths are stressed to about the same extent as nickel. The degree of stress usually present in copper and silver deposits is negligible.

Other pure metals which could be used, if their properties are needed, include gold, lead, antimony, and chromium. Some of these have distinct limitations. For example, it is difficult to plate thicknesses of more than a few thousandths of an inch of gold, so that gold is most likely to be useful as a lining or coating for an article made mostly of another metal. Antimony and chromium suffer from extreme brittleness.

In addition to these pure metals, many alloys can be electrodeposited, though none has acquired an important place in electroforming. Several recently developed alloy deposits, including cobalt-phosphorus, nickel-phosphorus, and cobalt-tungsten, have high hardness and strength and are further hardenable by heat-treatment.

Laminated metals are commonly used in electroforming and may have definite advantages. Thus, in waveguides, silver or copper can be used on the inner surface for electrical conductivity, backed by nickel or iron, for strength with low thickness. Parts which require corrosion resistance can be formed with nickel on the inside and outside surfaces, with iron sandwiched in between, to reduce cost or to conserve nickel. Many such opportunities for advantageous use of laminates will occur to the designer who is aware of this construction.

One other metal which should be mentioned is aluminium. It cannot be deposited from an aqueous solution, but non-aqueous solutions have recently been developed, with which thick, sound deposits can be made. Difficulties remain, which render electroforming with aluminium impractical for large production at the present time, but small numbers of small items can be made if the need justifies the cost. Improvements in the practicability of aluminium plating can be expected in the future.

DISPLACEMENT PUMP OF UNCONVENTIONAL DESIGN

(*Concluded from page* 432)

experience, it has been found that the cost of replacement of these chambers is lower than the maintenance cost of pumps of other types.

This type of pump would appear to have possibilities for application in various industries, especially in small installations with manual or mechanical drives, for pumping clean, dirty, or even viscous liquids. It could also be used as a vacuum pump.

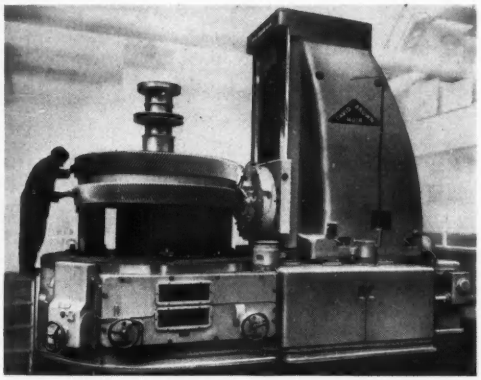
It is possible to line the elastic chamber with, or to make it entirely of, various plastics or other materials with specific chemically resistant properties, thereby making it suitable for use in chemical and allied industries.

New Materials, Processes and Equipment

TURBINE GEAR HOBBING MACHINE

A 100 in. turbine gear hobbing machine, first of a new standard range of large turbine wheel machines being built to B.S.I. specification No. 1498/1948, has recently been completed by David Brown Machine Tools Ltd., of Manchester, and has been installed in a temperature-controlled shop at David Brown and Sons (Huddersfield) Ltd., where it is now in production.

Weighing 50 tons, this machine will cut gears from 28 in. to 100 in. diameter with a maximum pitch of 2 D.P. Other principal dimensions and capacities are :—Maximum vertical traverse of hob slide, 70 in. ; maximum centre distance (hob to table), 68 in. ; hob length, 12 in. ; diameter of hob spindle (driving end), 4½ in. ; diameter of work-table, 108 in. ; diameter of work-table bore, 14¾ in. ; vertical traverse, 0·007 in. to 0·070 in. per rev. of the table ; hob speeds, 20/100 rpm ; power infeed, 0·0125 in. per rev. of the table.



A major factor in achieving the required accuracy is the provision of two independent dividing worm wheels, which are incorporated in the table drive. One is a fine-pitch master wheel, which is used to apply the finishing cut, and the other is a coarse-pitch wheel, used principally for roughing. This latter wheel is also used for setting-up and can be coupled to an independent motor to rotate the table at a comparatively fast speed.

Vertical travel of the hob is effected by a large screw, mounted centrally between guideways, which are relatively narrow to give increased precision. Adjustment of the lead screw is by means of two nuts, one of which is fixed and the other adjustable. A large seating on the hob saddle locates the hob slide, which can be swivelled through 180 deg. to accommodate right or left hand helical teeth.

The large hob driving spindle, on which is mounted the flywheel, is located in the final driving gear by large diameter multiple splines. A conical bearing at the front end of the spindle facilitates the accurate alignment of hob and spindle. This bearing has axial adjustment, whereby any errors due to excessive clearance can be rectified immediately.

The main gearbox, comprising change gears for the feed, spiralling, indexing, and prime mechanisms, is located at one side of the machine, whilst hob speed change gears are housed separately at the opposite side. Circulation of oil to the table unit is by two 1-hp gear pump motors mounted in tandem. One pump supplies oil to the table load relief while the other pump lubricates the two sets of dividing gears and the main gearbox. In addition, a standby pump is fitted and is brought into operation automatically if a fault develops in the oil flow. Gears and bearings in the hob slide are automatically and continuously lubricated. Another gear pump is used to circulate the cutting oil. In this case, too, a second pump is provided as a standby unit in case of power failure.

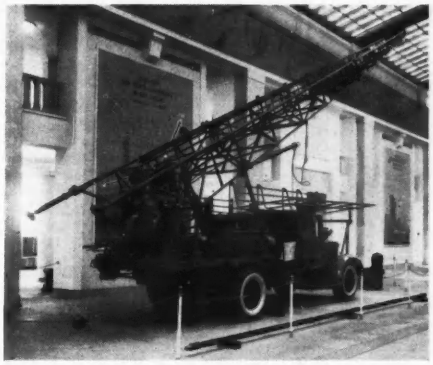
All the electrical control equipment is housed in a self contained cabinet. Eight motors are used to power the main drive, hob slide traverse, vertical travel rapid traverse of the table, and the duplicated lubrication and coolant pumps. The 10/20 hp variable speed main motor and 1-hp lubricant and coolant pump motors are arranged for direct current supply, so that, in case of a power failure, the drive can be switched to a secondary source, e.g., a battery set, to ensure uninterrupted cutting.

The independently operated hob slide and upright traverse motors, of 5 hp and 2 hp respectively, operate on an alternating current supply. Limit switches are fitted to prevent over-run.

In addition to the 100 in. machine, the new range of David Brown turbine wheel hobbers conforming to B.S.I. Specification No. 1498/1948 (Grade "A") includes a 150 in. machine, capable of hobbing turbine gears from 56 in. to 150 in. diameter (maximum pitch 2 D.P.), and a 200 in. hobber with a capacity of 90 in. to 200 in. (maximum pitch 1¼ D.P.). Both are of similar design to the 100 in. machine illustrated, with the exception that, in the case of the 200 in. hobber, swivelling of the hob slide is power-operated.

GEOLOGICAL DRILLING EQUIPMENT

A Russian mobile geological drill for experimental drilling was one of the exhibits at the Soviet pavilion at the Leipzig Fair in Eastern Germany in September, 1953.



Mounted on a ZIS-150 truck chassis, it is capable of drilling to a depth of approximately 325 ft with a 5¾ in. bit, and to 230 ft with a 7¾ in. bit. Maximum drill speed, according to the official prospectus, is 340 rpm.

A derrick, made of seamless steel tubing, and about 20 ft high in its working position, is hinged to the truck. It lies flat for travelling and can be erected to the vertical position in about 40 seconds by the truck engine, *via* a power take-off, which is also used to operate the drill and sludge pump.

GOODYEAR BELT GIVES TROUBLE-FREE SERVICE ON INTRICATE DRIVE

Extreme flexibility proved in woodwork factory

FOUNDED as a cooperage in 1878, the firm of Craigs Ltd., Widnes, has steadily expanded ever since. Today it combines a flourishing timber merchanting business with large scale woodwork manufacture for the building, chemical, engineering and textile industries.

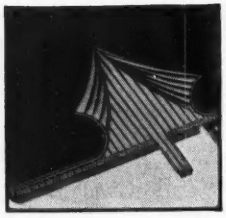
On the manufacturing side, Goodyear transmission belts are giving highly satisfactory performance under the toughest working conditions.

On this sanding machine, for example, a Goodyear Endless Cord Belt is giving outstanding service. Here, the 35 h.p. drive entails six changes of direction, combined with a regular lateral movement of the roller pulleys. Belt speed is over 2,000 feet per minute. Goodyear Endless Cord Belts were adopted after other types of belt had been proved unsuitable for the drive.

WHY GOODYEAR?

Why are Goodyear Industrial Rubber Products so completely reliable? Because they are the result of over 50 years' experience in rubber engineering. Because skilled Goodyear technicians supervise their manufacture at every stage. That is why Goodyear products are giving years of trouble-free service, the world over.

GOODYEAR ENDLESS CORD BELT



A belt with exceptional flexibility that permits greater speed over small pulleys. The load is carried by a central layer of robust, low stretch cords, continuously wound so that joints are eliminated. Balanced construction of the cords and of the tough fabric envelope ensure true running. The Goodyear Endless Cord Belt carries 33⅓ per cent. more load than any other belt of equal thickness.

★ **Goodyear Endless Cord Belts successfully tackle a complicated drive with six changes of direction. This is a sanding machine in the woodwork factory of Craigs Ltd., timber merchants at Widnes. Tough, dependable Goodyear belts are used exclusively throughout the plant. (NOTE. The guards have been temporarily removed from this drive to facilitate photography.)** ★

Illustrated and informative catalogues are available for all Goodyear Industrial Rubber Products. Please write to Dept. Y, Goodyear Tyre & Rubber Co. (G.B.) Ltd., Wolverhampton, stating the products in which you are interested.

GOODYEAR

INDUSTRIAL RUBBER PRODUCTS

TRANSMISSION BELTING · V-BELTS · CONVEYOR BELTING · INDUSTRIAL HOSE

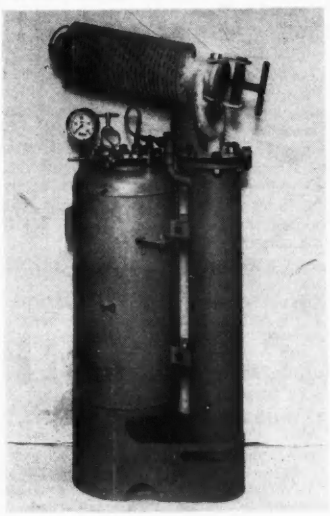
PORTABLE OXYGEN GENERATOR

In certain parts of the world, there has long been considerable difficulty in obtaining readily available supplies of oxygen when needed. Apart from this problem, there is the question of capital outlay on cylinders. Apparently, contrary to the normal practice in the United Kingdom of renting cylinders, overseas companies are often expected to buy these cylinders outright as, owing to local climatic and handling conditions, they are very often unsuitable for further use after operation, and certainly by their weight alone add considerably to the transport costs of oxygen.

With these problems in mind, a portable oxygen generator has been developed commercially and marketed by K. W. Chemicals Ltd., of London. This machine, known as the Oxybloc Portable Oxygen Generator, works on the principle of a chemical action taking place inside a cylinder. The gas given off by the chemical is scrubbed and purified, and then passes through a non-return valve to a cylinder, ready for use as oxygen of 99·5 per cent purity. The working procedure is as follows :—

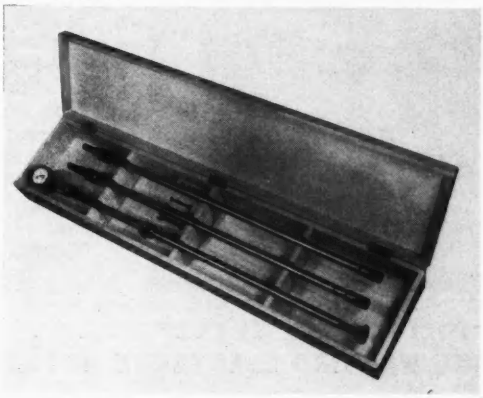
A cylindrical barrel of approximately 18 in. × 3·5 in. in diameter is loaded with four chemical candles, each of which is made of sodium chlorate with one or two admixtures, compressed into a solid cylindrical block. The topmost block is then partially ground with any sharp-edged implement, thereby producing a small heap of powdered chemical, combustion of which is initiated by a match or piece of burning wood. Within 15 to 20 seconds, a steady combustion takes place, after which the barrel, containing the burning chemical, is pushed home into a cylindrical retort, the end of which is then clamped tight. The impure gas given off by the chemical action travels down a feedpipe to a filter-unit, previously charged with a purifying chemical, and thence, *via* another pipe and a non-return valve, to the storage cylinder. As soon as the pressure in the storage cylinder is sufficient for the job in hand, the operation may be commenced, irrespective of whether the chemical action has finished or not. Normally, this chemical action takes place in about 15 minutes, each charge giving 35 cu ft of oxygen, the commencing pressure of the gas in the storage cylinder being about 200 psi.

In the United Kingdom, where distances are small and supplies of oxygen are readily available, such equipment is not an economic proposition. In many overseas territories, however, this generator, which weighs only 265 lb and measures 61 × 21 × 31 in., should be of great value, providing as it does a convenient, readily transportable means of supplying 99·5 per cent pure oxygen within 15 to 20 minutes of its being required.



CYLINDER BORE GAUGE

In response to an enquiry from the Department of Scientific and Industrial Research for a cylinder bore gauge suitable for checking bores of from 2 to 6 in. in diameter to a depth of 8 ft, British Indicators Ltd., of St. Albans, have developed such an instrument, with several novel features for overcoming some of the problems encountered in taking accurate measurements of this nature.



As shown in the illustration, the gauge can be broken down into three sections. Each section is threaded, to enable it to be interchangeable with any other section of the instrument. Thus, the total length of the gauge can be 2 ft 9 in., 5 ft 6 in., or 8 ft, for convenience in working at intermediate depths.

A special tension device is provided on the first section of the instrument, incorporating the transmission and centralising shoe of the gauge. The operation of the cylinder bore gauge necessitates the use of a central push rod operating from the plunger of the shoe to the plunger of the dial indicator ; consequently, although the push rod is made of light-alloy tubing, the total weight of the three sections becomes a factor affecting the sensitivity of the instrument. However, by varying the position of the adjusting collar which operates the tension of the supporting spring of the centre push rod, the dead-weight of the push rod can be counterbalanced. This latter feature has contributed extensively to the sensitivity of the instrument and it should be noted that operating pressures as low as 4 oz can be obtained at the gauging plunger.

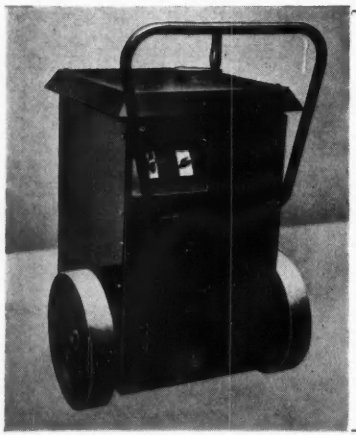
TEMPERATURE INDICATOR-CONTROLLER

The Accurate Recording Instrument Company, of Morden, Surrey, in conjunction with Watson House, have developed and are now producing a new temperature indicator-controller which has many applications in a wide industrial field. It will accurately indicate the temperature at any desired point, and control the flow of either gas or liquid fuel exactly in proportion to that temperature.

The instrument, which has a number of interesting features, employs no electricity, gives proportional control of the fuel supply, and the powerful liquid-expansion system used is quick-acting, positive, and sensitive to the slightest temperature changes. The valves can be readily and positively set to operate at any point on the scale, which may at present range up to 500° F, though a model operating up to 1000° F will be available shortly. Ambient temperature changes around

SOME EXAMPLES FROM THE COMPREHENSIVE RANGE OF

WELDING EQUIPMENT *by* PHILIPS

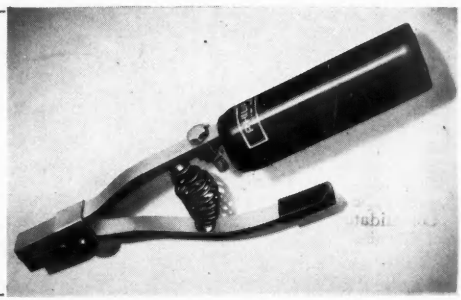


PHILIPS TYPE ES 3566
350 AMP. AIR COOLED
WELDING TRANSFORMER

A fully portable A.C. Welding Plant for medium and heavy fabrication. The transformer is suitable for connection to single phase or across 2 phases of a 3-phase 50 cycle supply. It is housed in a robust sheet steel cabinet — a built-in fan guarantees adequate cooling under all conditions.
Output : 60 — 350 Amps. Current continuously variable.
Arc Voltage : 24 — 34.5 Volt.
O/C Voltage : 75 — 80 Volt.
Primary Tappings : 190, 200, 220, 250, 380, 400, 440 and 500 Volts.
Total Weight : 3¼ cwt.

PHILIPS TYPE ES 1426 300 AMP.
ARC WELDING ELECTRODE HOLDER

Manufactured from high grade materials by the most modern factory methods employing arc and resistance welding, and High Frequency Heating. The resultant product is of excellent quality and finish and whilst being light in weight (20½-ozs.) its robust construction ensures a trouble-free life.
The Philips ES 1426 Electrode Holder is suitable for electrodes from 14 to 4 s.w.g. and operates without overheating over exceptionally long periods of continuous welding.



PHILIPS TYPE 1381/1
FULLY PORTABLE
WELDING TRANSFORMER

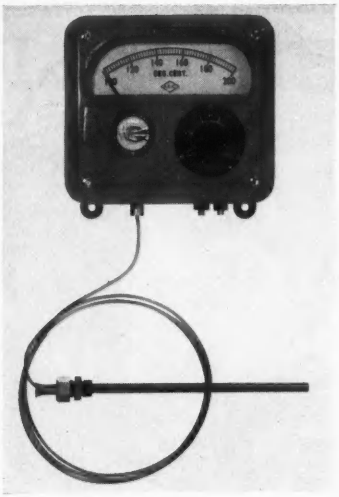
A fully portable A.C. Welding Plant for medium fabrications, sheet-metal welding, maintenance work and garage and agricultural repairs. Low initial outlay and low running costs are special features of this unit. Input links easily adjusted to permit connections to different supply voltages — 200, 225, 400, 440 volts; single phase 50 cycles, or across 2 phases of a three-phase system.
The welding current control is continuous over the entire range of 15 to 200 amps. Two current ranges are available :—
Low range — 15 to 100 amps. O/C voltage 80/100 volts.
High range — 30 to 200 amps. O/C voltage 40/50 volts.
Approximate dimensions — 1 ft. 6½ in. x 1 ft. 5 in. x 1 ft. 11½ in.
Approximate weight — 200 lb.

For full details of complete range, write for Philips Arc Welding Catalogue PD.3515

PHILIPS ELECTRICAL LIMITED

INDUSTRIAL GROUP, CENTURY HOUSE, SHAFTESBURY AVENUE, LONDON, W.C.2

INDUSTRIAL X-RAY EQUIPMENT · ELECTRONIC APPARATUS · LAMPS AND LIGHTING EQUIPMENT · ARC AND RESISTANCE WELDING PLANT AND ELECTRODES · MAGNETIC FILTERS · BATTERY CHARGERS AND RECTIFIERS · H.F. HEATING GENERATORS · RADIO AND TELEVISION RECEIVERS (W2338A)



the instrument head are automatically cancelled out by the "Accurate" bi-metallic compensating device. The indicating pointer and the control valve are both operated by the same unit, so that they cannot in any circumstances get out of relationship.

As shown in the illustration, the instrument is of compact and clean design, the cast aluminium case measuring only about 7½ in. wide by 6½ in. high by 3 in. deep.

VIBRATION METER

Greatly simplifying critical vibration testing, the new Type 1-117 Vibration Meter, manufactured by Consolidated Engineering Corporation, of Pasadena, California, may be used for field tests, for "trouble-shooting," in the laboratory, or as a gauge for production quality-control testing.

Completely portable, rugged, and compact, the meter weighs only 25 lb with three accessory filters installed and can be used wherever standard 115 volt, 50/60/400 cycle power is available. Suitably matched, self-generating pick-ups are the only external items required for its operation. Dimensions are 8¼ in. high × 10½ in. wide × 9½ in. deep.

As a maintenance tool, the 1-117 can be simply used with a hand-held velocity pick-up as a probe for tracking down and pin-pointing unusual or excessive vibration, thus often eliminating the need for tearing down an entire machine to locate the source of trouble.

As many as four suitably matched, self-generating pick-ups may be mounted on the body under test and their input fed to four connectors on the instrument's rear panel. Gain on each input channel can be adjusted individually. Where unwanted low-frequency signals interfere with the desired frequency, as in jet-engine or gas turbine testing, three accessory high-pass filters may be used to cut off sharply at 30, 70, or 110 cps. These filters plug into the case of the instrument and add nothing to its external dimensions.

Measured values of both linear and torsional velocity of motion and peak-to-peak displacement are indicated on a direct-reading scale. Full-scale peak-to-peak displacement measurements from 0·0005 in. to 1·5 in. and linear velocity measurements from 0·5 to 1500 ips average are possible through combinations of the various control settings. For velocity measurement, the flat frequency response is 5 to 5000 cps; for displacement, response is flat from 5 to 1000 cps. Close tolerance and extreme reliability over long periods of time are ensured by the circuitry of the four-stage single-channel amplifier, which incorporates negative feedback to ensure continuous stable operation.

Operation is simplified by front panel controls, which include a switch for selecting an internal calibration circuit. A 7-position attenuator and 5-position operation switch permit instant selection of sensitivity range and provide for operation as a linear amplifier for direct velocity measurements, or as an integrating amplifier for direct-displacement readings. Frequency is easily calculated from these two values. Thus, the meter can be used for a wide variety of applications without internal circuitry changes.

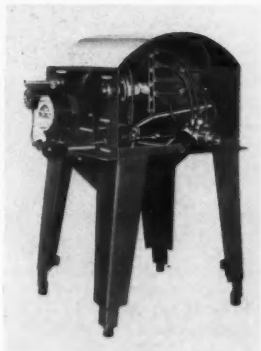
WASTE OIL FIRING UNIT

The standard model Kamel Portable Waste Oil Firing Unit, made by Kamel Products Ltd., of Liverpool, is suitable for central-heating boilers of between 100,000 and 350,000 B.T.U. The unit is designed to operate on waste oil and is especially suitable for garages where the disposal of waste oil is a problem. It can also operate on any ordinary fuel oil. The unit is so constructed that no alterations to existing boiler installations are required and the switch-over from coke to oil and back can be made in a few minutes.

Standing on telescopic legs, adjustable to suit any particular boiler, this unit consists of a small enclosed reservoir incorporating all the necessary valves, cocks, gauges, etc., and low-wattage thermostatically controlled immersion heater. The unit is supplied complete with a flash plate, back plate, and lighting rod, and merely requires the provision of a supply tank, which may be any container of approximately 40 gallons capacity.

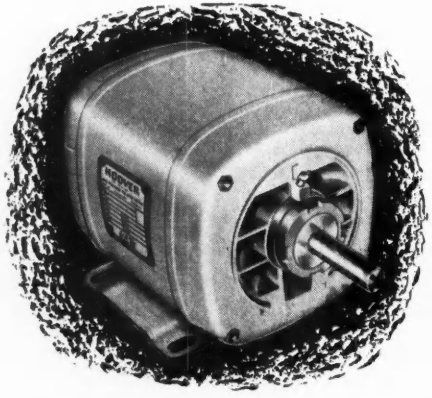
A pre-heater air coil, electric immersion heater and thermostatic air reducing valve, high-pressure jet blasting cock with interlock, variable oil supply valve, and spray cock with detachable head are incorporated. A small reservoir, holding approximately 2 gallons of oil, is included.

Main oil supply is by gravity feed and consumption is about 1 to 1½ gallons per hour for a small-sized boiler and 1½ to 2 gph for a medium boiler.



THE POWER OF A NAME

SHINING brightly among the immortal names of literature is that of Charles Dickens —tireless creator of some of the best loved characters ever to be portrayed by the printed word. In these modern times, Industry, too, has its famous names. Well to the fore is Hoover, which manufacturers everywhere immediately associate with the Hoover Fractional Horse Power Motor. Backed by extensive service facilities this sturdy 'fractional' represents a striking achievement in engineering skill; a motor whose matchless efficiency has been proved by industry time and time again.



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CLASSIFIED ABSTRACTS

Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns, are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.

ELECTRONICS

The Efficiency of Fluorescence in Cathode-Ray Tubes.

By A. BRIL and H. A. KLASENS. (From *Philips Technical Review, Holland*, Vol. 15, No. 2, August, 1953, pp. 63-72, 10 illustrations.)

THE screen of a cathode-ray tube is usually built up of one or more layers of crystals. With ZnS, for example, the size of the crystal may vary between one and some tens of microns; other substances, such as willemite (Zn_2SiO_4 — Mn), have smaller crystals. When a crystal of this kind is struck by an electron, the electron may leave the crystal without loss of energy (elastic collision); more frequently, however, the electron will impart some, or the whole, of its energy to the crystal (inelastic collision) and the energy thus released is transferred mainly to the electrons present in the crystal. Within the crystal, then, a swarm of " excited " electrons is formed, which possess extra energy of the order of 10 eV. These excited or secondary electrons will, if the substance is not a phosphor, ultimately yield this energy to the crystal lattice without radiation, in the form of heat. With phosphors, on the other hand, some of the excited electrons transfer their extra energy directly or indirectly to so-called luminescence centres, which can then emit a quantum of light. Other secondary electrons will leave the crystal immediately (secondary emission), and this is important from the point of view of the charging of the screen.

To obtain quantitative results which are independent of surface effects, the investigation of these phenomena is restricted to high electron velocities, corresponding for example to acceleration potentials of 10 to 50 kV. This range of potentials, whereby electrons will penetrate crystals such as ZnS to a depth of 1 to 25 μ is also most interesting from the point of view of technical applications.

This article describes special measuring equipment for determining the intrinsic conversion efficiency of electron energy into luminous energy. The results of measurements taken from a number of different phosphors with varying temperature and primary electron energy are presented. Additional measurements give the luminous intensities at the front of conventional types of screen, with and without aluminium backing. There are optimum values for the screen and backing thicknesses. Theoretical support is also lent to the arguments presented.

FATIGUE TESTING

The Fatigue Testing of Structures by the Resonance Method.

By R. B. HEYWOOD. (From *Schweizer Archiv, Switzerland*, Vol. 19, No. 8, August, 1953, pp. 249-260, 28 illustrations.)

IN a paper presented at the 1953 International Discussions on Fatigue in Zurich, organised by the Swiss Association for Materials Testing, descriptions are given of several fatigue-testing machines and rigs, in which parts or structures can be tested at a frequency close to that of resonance. Special reference is given to the methods used for testing aircraft structures, as this industry has a particular interest in the fatigue life of actual components, differing from that obtained in testing small laboratory specimens.

The resonant type of fatigue machine comprises three parts, *viz.*: The resonating system, the means of excitation, and the control of load. The term " resonance " refers to systems in which the frequency of vibration is near to, but not necessarily precisely at, the resonant frequency. This method of testing may entail some preliminary work in order to arrive at the correct load distribution throughout the structure but, once this has been done, the test itself is rapid.

Of particular interest is the new " slipping clutch " type of exciter, which not only forms the means of excitation, but also controls the amplitude of vibration. Essentially, this comprises a crank and connecting rod type of exciter, in which a clutch is introduced into the mechanism, so that slipping can occur when connecting rod forces exceed a pre-set value. The clutch housing is mounted on the structure by means of a pin or by gimbal bearings, and the clutch itself comprises two plastic blocks which grip the tubular connecting rod by lateral forces. The adjustment of pressure between the blocks varies the frictional force and hence the driving force in the connecting rod. The difficulty of starting the vibration in the resonating system is overcome by the slipping clutch, which enables the driving motor to be started with the clutch entirely free. When the motor reaches speed, pressure is slowly applied to the clutch, so that the required energy is gradually transferred to the resonating system.

The design of slipping clutch units for a number of different applications is described.

FLOW MECHANICS

Analysis of Viscous Flow Through Axial-Flow Turbo-Machines.

By T. P. TORDA, H. H. HILTON, and F. C. HALL. (From *Journal of Applied Mechanics, U.S.A.*, Vol. 2, No. 3, September, 1953, pp. 401-406, 9 illustrations.)

THE several methods which have been developed to analyse flow through axial turbo-machines may be divided into two main categories:—In the direct method, the flow variables are derived from given geometric configurations, while in the indirect method the geometric configuration of the blades is determined from a desired distribution of the flow parameters.

Sources and sinks, vortex distribution, or conformal mapping may be employed in the direct method of analysis, to determine the flow field around the individual blades of turbo-machines. However, the interference of the blades, when arranged in cascades, is difficult to determine by the use of this method, and the results are valid only if the cascade blades are far apart.

The indirect method of analysis treats the passages between the cascade blades as channels and is, therefore, the more suitable of the two methods for the analysis of viscous effects in turbo-machines. H. Lorenz, who first developed the indirect method of analysis, simplified the mathematical formulation of the problem of flow through blade systems by means of a continuous, axially symmetric force field. The Lorenz theory, representing an infinitesimally spaced blade system, can

Here we go round the Standard Bush...

We are reckoned to be one of the leading suppliers of plain bearings and bushes in the country, and indeed in the world. We mention this in passing. Now, about the STANDARD idea... Whether you produce on a very large scale or a modest one you must benefit from the use of standard components. Take bronze bushes. If you have these specially made to your own sizes you incur costs for drawings, patterns, tools, etc. and take up time in a way that may well be unnecessary. Unnecessary because Glacier make Standard bushes in ranges sufficiently wide to cover all your probable requirements. Our Standard range of Bronze Bushes alone has 191 variations in perfect series, graduating in length, in nominal bore, in nominal housing size — plus five standard grooving designs. You order your bushes from stock for immediate delivery, without restriction as to quantity. We supply them, finished and ready in Glacier bronze, with an allowance in the bore for final sizing after assembly. *Whether it's bronze bushes, wrapped bushes or bronze bars* . . . **THAT'S THE LOGIC BEHIND—**

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be used as a first approximation for calculating the pressure distribution, velocity distribution, blade shape, and the torque of modern turbo-machines with their closely spaced blades.

In this paper, the Lorenz theory has been extended to the viscous, laminar, incompressible flow through axial-flow turbo-machines with infinitesimal blade spacing. Expressions are derived for the velocity components, pressure, power input, and output for abitrary blade surfaces. A numerical example is presented and the flow variables and blade surfaces are plotted.

Steady Flow in Contracted and Expanded Rectangular Channels.

By F. ENGELUND and J. MUNCH-PETERSEN. (From *La Houille Blanche, France*, Vol. 8, No. 4, August-September, 1953, pp. 464-474, 9 illustrations.)

THE comparison between standing waves which may occur at the free surface of high velocity flows and the waves observed in compressible fluids at supersonic regimes is well known ; for example, the former make, with the side-walls of the channel, angles which are quite analogous to Mach angles. The theoretical investigation of these phenomena, however, does not seem to have been carried very far ; up to now, usually an approximation, apparently corresponding to the classical hypothesis of the shallow-water theory, has been accepted.

Experiments have shown that, if such an approximation is perfectly justified for very high Froude numbers, it becomes very doubtful when, with a decrease in the relative velocity, Froude numbers near unity are approached. Moreover, it appears that the accepted approximation is really admissible, even at high velocity, only for relatively wide and shallow channels.

Starting from basic equations of hydrodynamics, the authors derive equations which give the shape of the free surface and find, on the whole, the same results as those obtained by experiment. More especially, they are able to evolve an expression of Mach angles which takes into account the Froude number and the relative depth at the same time.

In addition, two applications are presented, one for the case of a symmetrical channel contraction and the other for the case of an expansion channel in supercritical flow.

These two cases have formed the object of measurements on scale models, and the results, for the most part, agree very satisfactorily with those of the proposed theory.

The authors define the hypotheses on which their study is based ; they describe the very wide field of application of their theory and indicate the course to be followed in order to improve it.

MACHINE SHOP PRACTICE

Wear of Carbide Tools.

By A. J. PEKELHARING and R. A. SCHUERMANN. (From *The Tool Engineer, U.S.A.*, Vol. 32, No. 4, October, 1953, pp. 51-57, 10 illustrations.)

Progress made in Holland in the standardisation of surface roughness led to an investigation of finish turning with single-point tools. In the course of this work, it became clear that the wear occurring on the end clearance face of the tool is important.

Little quantitative data have been published concerning the influence of tool wear on the surface roughness produced in finish turning. Investigations of the effect of tool form and feed on surface condition are of little practical value, as long as the tool form is regarded as a fixed quantity.

In the course of work on the wear of carbide tools, a number of practical applications was made, as follows :—

(1) Production of a predetermined surface roughness on several workpiece materials under shop conditions.
(2) Determination of optimum end-cutting-edge angle for carbide finishing tools.
(3) Testing of free machine steel for "finishability."
(4) Testing of carbide for wear resistance.

The results of these investigations indicate that, in finishing operations, surface condition and dimensional accuracy are in many cases determined by formation of grooves and nose wear on the carbide tool. It is also established that prevention of phenomena caused directly by groove formation and nose wear, such as vibration and sparking, should be the major considerations in the choice of the end-cutting angle, and that the quality of carbide can be determined by means of nose tests.

From these considerations, the conclusion is drawn that the formation of grooves and nose wear at the tool nose are the dominating factors in the field of finish turning with single-point carbide tools.

PRODUCT DESIGN

The Use of Models in Design.

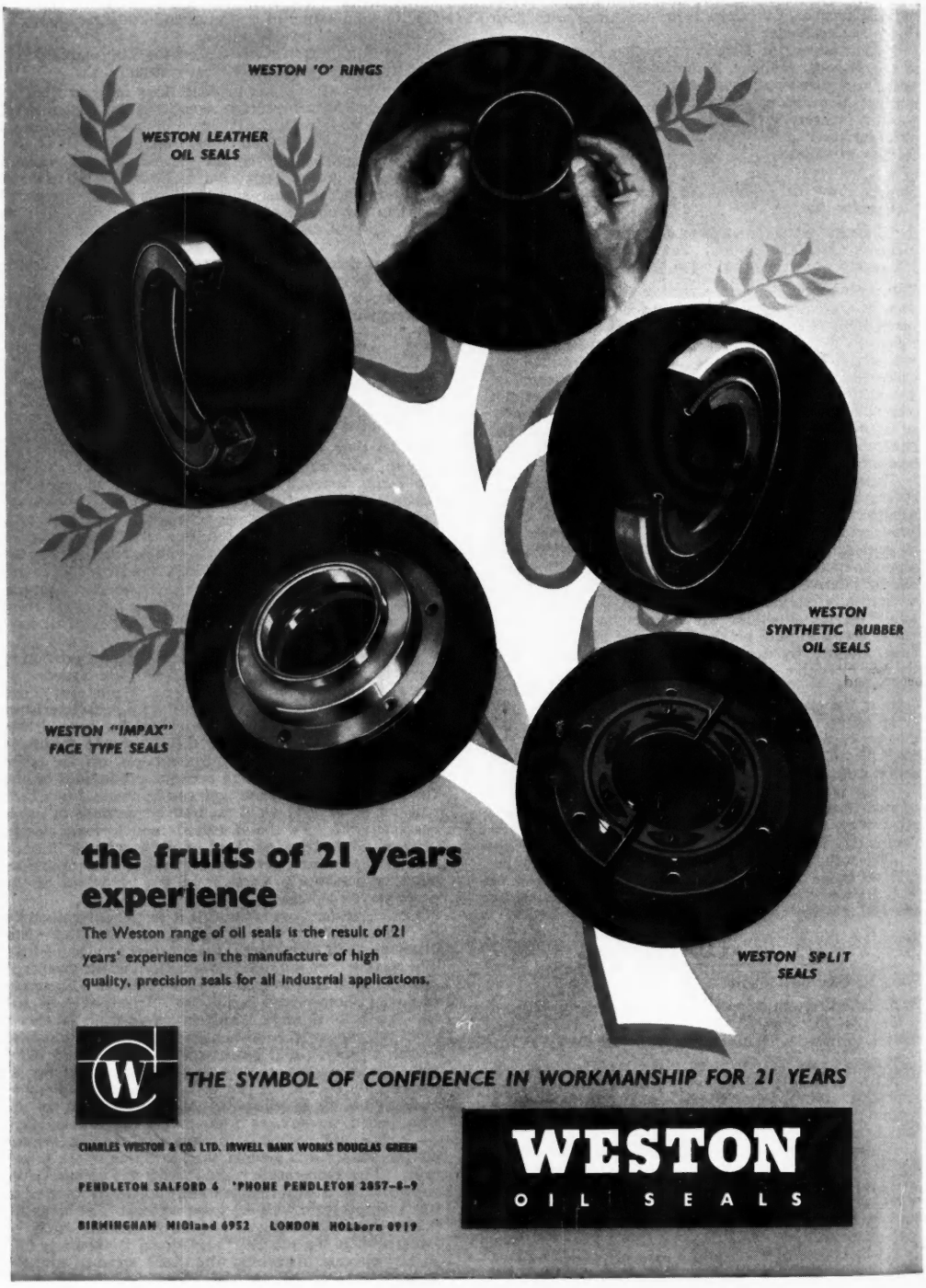
(From *Product Engineering, U.S.A.*, Vol. 24, No. 9, September, 1953, pp. 177-184, 12 illustrations.)

BECAUSE they are relatively inexpensive, in many cases easy to make, and a direct source of design data, models are being assigned a role of primary importance in product design. In general, more than one type of model may be used in predicting the behaviour of a given prototype. Thus, one type may be similar in appearance to the prototype ; another, from which just as accurate predictions can be made, may bear no resemblance to the prototype. In some cases, several characteristics of the prototype may be predicted from one particular model, while only one characteristic may be predictable from another model.

Four general types of model are useful in predicting the behaviour of the prototype. These are classified as true, adequate, distorted, and dissimilar models. True models, which can be used for predicting characteristics in relation to different design parameters, have all the significant characteristics of the prototype faithfully reproduced to scale. Adequate models, on the other hand, are those from which accurate predictions of one characteristic of the prototype can be made, but which will not necessarily yield accurate predictions of other characteristics. In the distorted model, some design condition has been violated, while dissimilar models bear no apparent resemblance at all to the prototype, but give accurate predictions of the behaviour of the prototype by suitable analogies.

An important use of models is in the determination by photo-electric techniques of stresses and their distribution in metal parts under actual service loading. The models used are true reproductions of the prototype and therefore supply accurate data directly. There are two main photo-elastic techniques. In one of these, the two-dimensional method, models are cut from flat sheets of special materials, and when loaded in a manner similar to the prototype and examined under polarised light, yield configurations of light and dark bands, known as fringes. By the simple process of counting fringes and multiplying by a calibration constant, known as the fringe value, the stresses in the model can be calculated

The second method is by means of three-dimensional models, loaded in a manner similar to that of the prototype. The temperature is then raised to a certain value, known as the critical temperature, and slowly lowered to room temperature with the loads acting. The loads are then removed, leaving a system of strains fixed or "frozen" in the model. The model is then cut into slices, without disturbing the fixed strains, and the stresses determined in the slices, as in the two-dimensional method.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SYMPOSIUM ON ENGINEERING METROLOGY—NATIONAL PHYSICAL LABORATORY

(*Concluded from page* 416)

for cylindrical bores, has been applied successfully by W. Lueg for controlling surface finish and wear of bell-mouthed drawing dies.

One interesting example of how purely scientific investigation and developments may ultimately benefit industry was demonstrated by improved methods in producing diffraction gratings. For a number of years, the N.P.L., in collaboration with Sir Thomas Merton, developed the Merton nut principle for producing diffraction gratings. Instead of ruling on a plane surface, a fine screw-thread is produced on a highly polished steel cylinder by means of a diamond chisel edge. To avoid periodic errors, the ruling is co-axially transferred by another diamond, the first screw being surrounded by a flexible nut. In this way, very accurate rulings have been obtained, with pitches of from 200 to 15,000 per linear inch. The plane gratings themselves are produced by a replica method and such gratings, owing to their accuracy, are much in demand. A diamond-turning lathe has been specially constructed for producing such screws, the surface of which is first diamond-turned to a finish of 1 micro-inch, using a blended facet tool. One new idea for the use of improved fine gratings of this kind is in actual measurements over longer distances. For this purpose, two of these gratings are placed one on top of the other, with a small, variable inclination, if possible. This causes the so-called *moiré* effect, in which alternate white and black horizontal bands (actually interference fringes) become visible, the distance between the fringes being easily adjustable. To use this principle for very accurate measurements, light can be transmitted through a slit and projected on to photocells. If the gratings are moved a slight amount axially, as was demonstrated on a model in the Light Division, the number of fringes can easily be counted electronically and in this way the amount of movement determined. This technique may give rise to another principle for the automatic control of machine movements.

FATIGUE TESTING OF WIRE ROPES

(*Concluded from page* 426)

(iv) The methods of loading (by means of one-, two- or three-sheave arrangements) produce considerable differences in fatigue behaviour, as follows :—

(a) With the single-sheave system, the six-strand fibre-core ropes reach maximum life values with sheaves of medium size, whereas the steel-core ropes show steadily increasing life values with increasing sheave diameters, for the range of sheaves used in the tests.

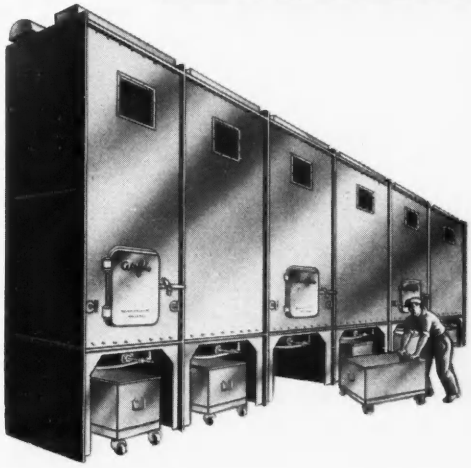
(b) The two-sheave system, tried only with the steel-core ropes, produces more severe loading conditions than the single-sheave system.

(c) The three-sheave system with a re-entrant angle gives the most severe loading conditions, owing to the action of the central sheave, which increases the wear of the individual wires. An examination of the results in Table II shows that the number of cycles to failure is diminished in all cases with this system. The values obtained are between 5 and 10 times smaller than with the single-sheave system, for the various ropes tested.

CONCLUSIONS.

The fatigue tests on the apparatus described above are fairly rapid and are sufficiently representative of true service conditions. Investigations will be extended in order to collect further comparative data and to develop a standard acceptance test for the fatigue strength of ropes, in addition to the static tests now used.

DUST COLLECTION IN A BIG WAY!



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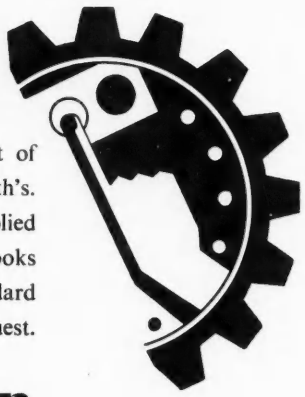

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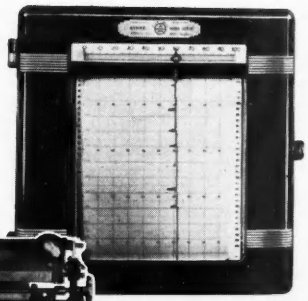

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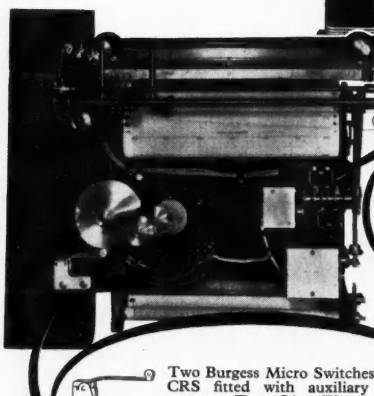

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NEWS OF THE MONTH

PERSONAL

Sir Archibald J. Boyd, managing director of Metropolitan-Cammel Carriage and Wagon Co. Ltd., Saltley, Birmingham 8, will retire at the end of this year, but will continue to serve on the Board and will be available in an advisory capacity. **Mr. H. N. Edwards** has been appointed to the position of managing director. **Mr. Norman Haddon** has been appointed production general manager and a director of the company, in succession to **Mr. A. T. Cheesley,** who is retiring on December 31st. **Mr. Harry Green,** special director and chief engineer (design), will join the Board on January 1st next.

Mr. W. L. Brown has been appointed chief engineer of Transformers (Watford) Ltd., Sandown Road, Watford, Herts.

Rear-Admiral L. N. Brownfield, C.B.E., has been appointed Admiral Superintendent at H.M. Dockyard, Devonport.

Mr. A. R. Clague, M.Eng., A.M.I.E.E., A.M.I.Mech.E., has been appointed chief generation engineer (operation) South Eastern Division, British Electricity Authority.

Mr. L. H. Coney, M.B.E., has been appointed lubricants co-ordinator of Shell-Mex and B.P. Ltd., Shell-Mex House, Strand, W.C.2.

Mr. D. B. Cunningham, secretary of Lithgows Ltd., Port Glasgow, has been elected to the Board.

Mr. L. J. Dennett, of Decca Radar Ltd., 1-3 Brixton Road, London, S.W.9, has been appointed general manager of Decca Radar (Canada) Ltd.

Dr. John Dick, B.Sc., M.A., M.I.Mech.E., Reader in Engineering Science, University of Oxford, has been appointed to the Chair of Engineering and Drawing, University College, Dundee, as from April 1st, 1954.

Sir Roger Duncalfe, chairman of British Glue & Chemicals Ltd., has been elected President of the British Standards Institution to succeed **Viscount Waverley, P.C., G.C.B., G.C.S.I., G.C.I.E., F.R.S.,** whose three-year term of office had ended in accordance with the B.S.I. constitution.

Mr. E. G. Foden, B.Sc., has been appointed head of the Tender Engineering Department of the British Thomson-Houston Co. Ltd., 20 Neasden Lane, London, N.W.10, in succession to **Mr. P. H. Harding,** who has retired after 50 years of service with the company.

Mr. O. R. Guard, former chairman of the Southern Gas Board, has been appointed deputy chairman of Associated British Engineering Ltd., 32 Duke Street, London, S.W.1.

Mr. J. D. Greenway, C.M.G., late of the Foreign Office, has been appointed overseas envoy, and **Mr. R. L. Beverley, D.F.C.,** has been appointed home sales manager, of the Turner Manufacturing Co. Ltd., Wulfruna Works, Villiers Street, Wolverhampton.

Admiral Sir Cecil H. J. Harcourt, G.B.E., has been elected to the Board of Dewrance and Co. Ltd., 165 Great Dover Street, London, S.E.1.

Mr. W. E. Hardeman, manager of the tyre design division of the Dunlop Rubber Co. Ltd., Fort Dunlop, Birmingham 24, has been appointed chief tyre development engineer. **Mr. L. J. Lambourn** has been appointed manager, and **Mr. E. S. Tompkins,** deputy manager, of the tyre design division. **Mr. H. R. Fletcher** has been appointed manager of the aircraft tyre division.

Mr. J. Holmes, formerly export manager of Thos. W. Ward Ltd., Sheffield, has been appointed sales manager of Thos. Storey (Engineers) Ltd., Stockport.

Wing Commander N. J. Hulbert, D.L., M.P., has been elected to the Board of Westland Aircraft Ltd.

Mr. G. L. R. Jones, A.M.I.E.E., technical director of G.P.U. Ltd., is now in charge of the Company's new advisory technical offices at Lloyd House, 44 Bryanston Street, London, W.1.

Mr. W. B. Laing, M.I.E.E., A.H.W.C., director and joint general manager of Bruce, Peebles & Co. Ltd., Edinburgh 5, has been appointed general manager of the company.

Mr. W. G. Lisle has been appointed manager of the Hydraulics Department of Sperry Gyroscope Co. Ltd., Great West Road, Brentford, Middlesex.

Mr. I. M. Lyon, general manager of the Renfrew and Dumbarton Works of Babcock & Wilcox Ltd., is retiring on December 31st, but will continue to serve in a consulting capacity. **Mr. D. D. Cruickshank** has been appointed general manager, and **Mr. T. Carlile,** assistant general manager of the Renfrew and Dumbarton Works, as from January 1st, 1954.

Mr. H. C. Margrett has been appointed manager of the business development department of the General Electric Co. Ltd., Magnet House, Kingsway, London, W.C.2, in succession to **Mr. P. H. Nye,** who has recently retired.

Mr. R. B. Potter, chairman of Simon-Carves Ltd., Stockport, has been elected to the Board of the Davy and United Engineering Co. Ltd., Park Iron Works, Sheffield.

Mr. H. C. Pritchard, B.A., F.R.Ae.S., has been appointed deputy general manager of Elliott Brothers (London) Ltd., Century Works, London, S.E.13.

Mr. P. W. Redway, sales manager, has been elected a director of the Skinningrove Iron Co. Ltd., Saltburn-by-the-Sea, Yorkshire.

Mr. A. Robertson has been appointed general manager of Alley and MacLellan Ltd., Worcester, following the retirement of **Mr. J. R. Wilson** from the position of managing director. Mr. Wilson will continue to serve on the Board of the company.

Mr. E. N. Robinson, LL.B.(Lond.), deputy chairman of A. Reyrolle & Co. Ltd., has been elected to the Board of C. A. Parsons & Co. Ltd., Heaton Works, Newcastle-upon-Tyne.

Dr. A. Rosen, M.I.E.E., has been appointed telecommunications consultant in the engineering organisation of British Insulated Callender's Cables Ltd., in succession to the late Dr. Hans Carsen.

Mr. F. Short has been appointed small tools representative of Burton, Griffiths & Co. Ltd., for South Wales, at their branch office at Index Works, Curran Road, Cardiff. Tel. No.: Cardiff 24111.

Mr. Mervyn W. Shorter, a director and general sales manager of the Westinghouse Brake and Signal Co. Ltd., 82 York Way, King's Cross, London, N.1, has been appointed managing director of the Company.

Mr. Ewen H. Smith has been elected chairman, and **Mr. P. L. Jones, M.C.,** has been elected vice-chairman of the National Association of Marine Engine Builders.

Mr. A. W. Wade, M.I.Ex., has relinquished his position as export manager of Blaw Knox Ltd., to take up the position of general manager of Con-Mech (Engineers) Ltd., 4 Southampton Place, London, W.C.1.

Dr. A. C. Walshaw, M.Sc., M.I.Mech.E., has been appointed Head of the Department of Mechanical Engineering, College of Technology, Birmingham.

Mr. Christopher Wilson has been appointed assistant to the general manager of the Machine Tool Trades Association, Victoria House, Southampton Row, London, W.C.1.

MR. GEORGE WILLIAM CLARKE

Mr. George William Clarke, A.M.I.Mech.E., M.I.P.E., the "G.O.M." of manufacturing engineers in Standard Telephones and Cables Ltd., died on Oct. 1, aged 66. He was currently engaged with others on the design of submarine repeater housings.

Mr. G. W. Clarke, amongst his other wartime activities, made an outstanding contributior to safety in the factories in connection with the operation of Power Presses. He had a large circle of friends, both inside and outside the Company, who deeply appreciated his kindness and had a high respect for his integrity and advice. He was a man of great inventive ability with a high sense of duty and clear and penetrating mind, and an enormous capacity for work. He set himself a high standard and inspired others by his example.

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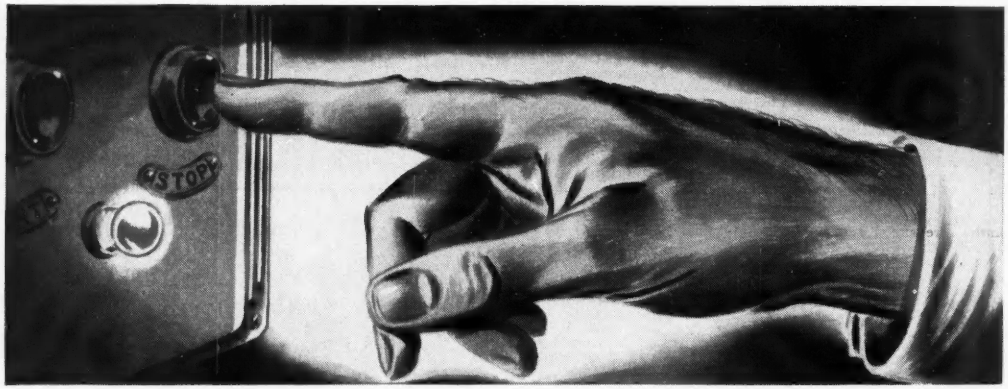

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BUSINESS NOTES

Problems of Aircraft Production. The second Conference on "Problems of Aircraft Production" arranged by the Southern Section of The Institution of Production Engineers, will be held on December 18th and 19th at the University of Southampton. It will provide an opportunity for executives in the aircraft industry to hear the views of eminent authorities and to discuss with them some of the day-to-day problems of aircraft production.

The Rt. Hon. A. T. Lennox-Boyd, P.C., M.P., Minister of Transport and Civil Aviation, will be the principal speaker at the opening luncheon.

Mr. D. Keith-Lucas, B.A., M.I.Mech.E., F.R.Ae.S., chief designer of Short Bros. & Harland Ltd., will present a Paper on "The Trend of Design."

Mr. G. H. Dowty, F.R.Ae.S., chairman and managing director of Dowty Equipment Ltd., and Mr. S. P. Woodley, M.B.E., superintendent of the Supermarine Division, Vickers-Armstrong Ltd., will present Papers on "Production Problems arising from the Trend of Design."

Mr. B. S. Shenstone, chief engineer of British European Airways Corporation, and Air Marshal Sir R. Owen Jones, K.B.E., C.B., A.F.C., controller of engineering and equipment at the Air Ministry, will present Papers on "User Problems affecting the Industry."

Sir Frederick Handley Page, C.B.E., Hon. F.R.Ae.S., F.C.G.I., chairman and managing director of Handley Page Ltd., will sum up the Conference.

Fireproof Belting for the Coalmines. Conveyors in all British coalmines are to be fitted with fire-resistant belting. The National Coal Board has issued instructions that 10 per cent of the total belting in use must be of approved fire-resistant type by January 1st. This percentage is to be increased as circumstances permit until uniformly applied throughout the coalfields.

Metropolitan-Vickers Electrical Co. Ltd. and **British Insulated Callender's Cables Ltd.,** announce that as from the 2nd November, 1953, arrangements have been made whereby Metropolitan-Vickers will take over the manufacture, sale and servicing of resistance welding and heating machines formerly manufactured by British Insulated Callender's Cables.

The new arrangement will add considerably to the already extensive Metrovick range of arc welding and resistance welding equipments by the addition of further models of pedestal spot, slow butt, hand flash butt and automatic flash butt welders; also rivet heaters, resistance brazing machines and wire rope parting machines.

Brooks & Walker Ltd., Engineers' Suppliers, 47 Great Eastern Street, London, E.C.2, announce that their Coventry branch is now at Swan Lane, Coventry.

Mr. R. Catchpole has rejoined the Company and will act as Eastern Counties Representative for Brooks & Walker Ltd. from his address at 165 North Walsham Road, Sprowston, Norwich.

Coventry Radiator and Presswork Co. Ltd., Coventry, have completed arrangements with the Dravo Corporation, Pittsburgh 22, Pennsylvania, for the manufacture and sale of "Counterflo" and "Paraflo" oil- and gas-fired warm-air space heaters in Great Britain, Eire and British Colonies and Protectorates, with non-exclusive rights in India and Pakistan.

Wickman Ltd., Coventry, have been appointed sole selling agents for Edouard Dubied et Cie., manufacturers of high production lathes, copying lathes and tool and cutter grinding machines, Neuchatel, Switzerland.

Midland Silicones Ltd. are to hold an exhibition of silicone rubber on their premises at 19, Upper Brook Street, London, W.1. There will be a comprehensive display of industrial and other uses of silicone rubber together with demonstrations of its properties and the latest grades developed. The exhibition will open on December 2nd and will be open each day from 10 a.m. to 6 p.m. (Saturday 10 a.m. to 1 p.m.) until December 10th. Invitations will gladly be supplied on application to Midland Silicones Ltd., 19 Upper Brook Street, London, W.1. Tel.: Grosvenor 4551.

The Houdry Process Division of World Commerce Corporation, S.A., announce the removal of their offices to 270 Park Avenue, New York 17, N.Y.

Westool Ltd., St. Helen's Auckland, Co. Durham, announce that they are now manufacturing electro-magnetic brakes and clutches under licence from the Warner Electric Brake and Clutch Company, Beloit, Wisconsin.

Wickman Limited, Coventry, announce the opening of a London branch factory and offices at Oxgate Lane, Cricklewood, N.W.2. The Export Department will also be located at this new address.

Apart from a showroom which is being installed in the new premises, a production unit is being established for the manufacture of Wimet tools, and a separate Electro-Mechanical Department laid down for the production of high frequency induction heating equipment, electro-erosion machines and machines for cutting tool reservicing.

The Hoyt Metal Company of Great Britain Ltd., Deodar Road, London, S.W.15, announce the construction of a new factory to be operated by their subsidiary company, the Hoyt Alloys & Chemicals of Australasia Pty. Ltd., 82 Pitt Street, Sydney, N.S.W., Australia.

Macrome Ltd., Aldersley, Wolverhampton, have been appointed exclusive sales managers for the Hand Tool Division of the Bren Manufacturing Co. Ltd., Gateshead 11. The Brenco chrome vanadium tool range includes ring wrenches, open ended spanners, combination spanners and sockets in Whitworth, B.S.F., American, Metric and Unified sizes.

HOT-CLOSING OF RIVETS

Cold heading of rivets used in stressed assemblies leaves much to be desired, owing to the serious disturbance to the structure of the headed metal, which is often so fatigued by the process as to break away from the rivet stem immediately any strain is imposed.

After a careful investigation of the problems involved, Standard Resistance Welders Ltd., decided to build a modified version of their vertical slide head air-operated projection welder. A salient feature of this machine is the close automatic control established over such operating variables as electrode pressure, heating current and time. The results obtained were more than encouraging. Not only were the rivets closed more tightly than formerly, but the grain-flow in the rivet was practically undisturbed; the headed portions were uniform in size and shape, and the whole process was carried out in a tenth of the usual time with a complete absence of the clattering cacophony which had previously been an inevitable, but nerve-wracking accompaniment to rivet closing operations.

A great deal of experience has now been accumulated about hot-closing as a regular production process, and production engineers having rivetting problems to solve are invited to contact Standard Resistance Welders, Mucklow Hill, Halesowen, Nr. Birmingham.

NEW X-RAY DIFFRACTION EQUIPMENT

Philips Electrical Ltd., Century House, Shaftesbury Avenue, London, W.C.2, have recently introduced a new X-Ray Diffraction Unit which, it is claimed, covers the immediate as well as the long term needs of any research worker engaged in this field.

Known as the PW.1010, the new unit employs the well-known Philips system of interchangeable "sealed-off" X-ray tubes with different anode materials and having high-transmission mica beryllium windows. The need for a separate and continuously operated vacuum system is thus eliminated. The equipment has only to be switched on and it is ready for use. The high tension generator employs a single thoriated tungsten filament valve and the smoothed D.C. output is stabilised electronically to within 0·1 per cent. Variations in mains voltage up to 10 per cent plus or minus are compensated for automatically. The stabilisation is unaffected by frequency drift. Each working position on the camera table is provided with an electro-magnetically operated shutter controllable manually or by built-in time switches. A comprehensive system of interlocks guards against mishaps resulting from failure of mains or water supplies and incorrect handling. The PW.1010 is offered with a wide range of precision cameras although any type of camera can be employed, including a Weissenberg goniometer. For this reason provision is made for the X-ray tube to be used either vertically or horizontally or by means of a cable, away from the unit altogether. The high degree of stabilisation makes the PW.1010 particularly suited to Geiger-Counter spectrometry with or without an automatic recorder. The equipment is stated to comply with the recommendations of the International Commission on X-ray Protection.

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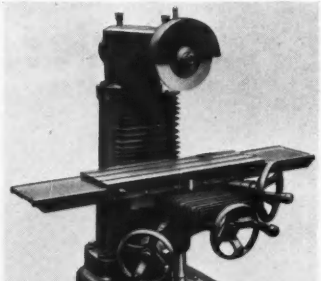

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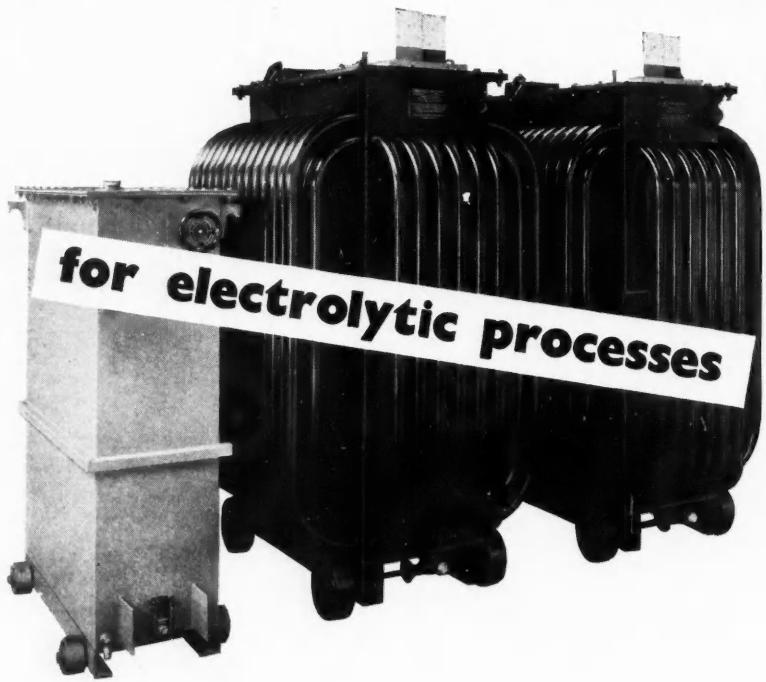
Oil Immersed Rectifier Equipment



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